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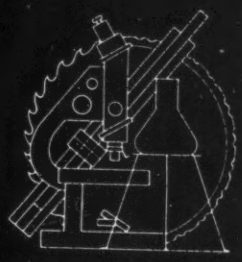

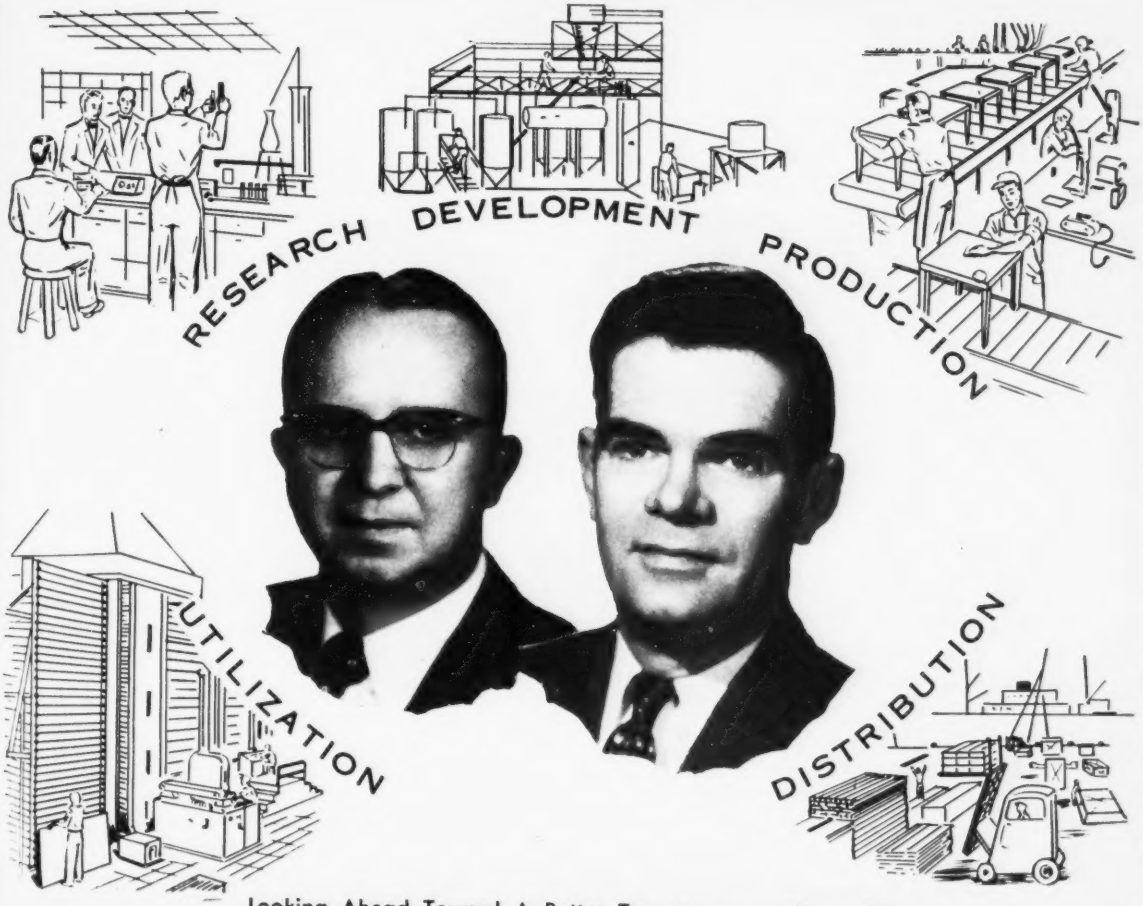

Looking Ahead Toward A Better Tomorrow . . . Page 99

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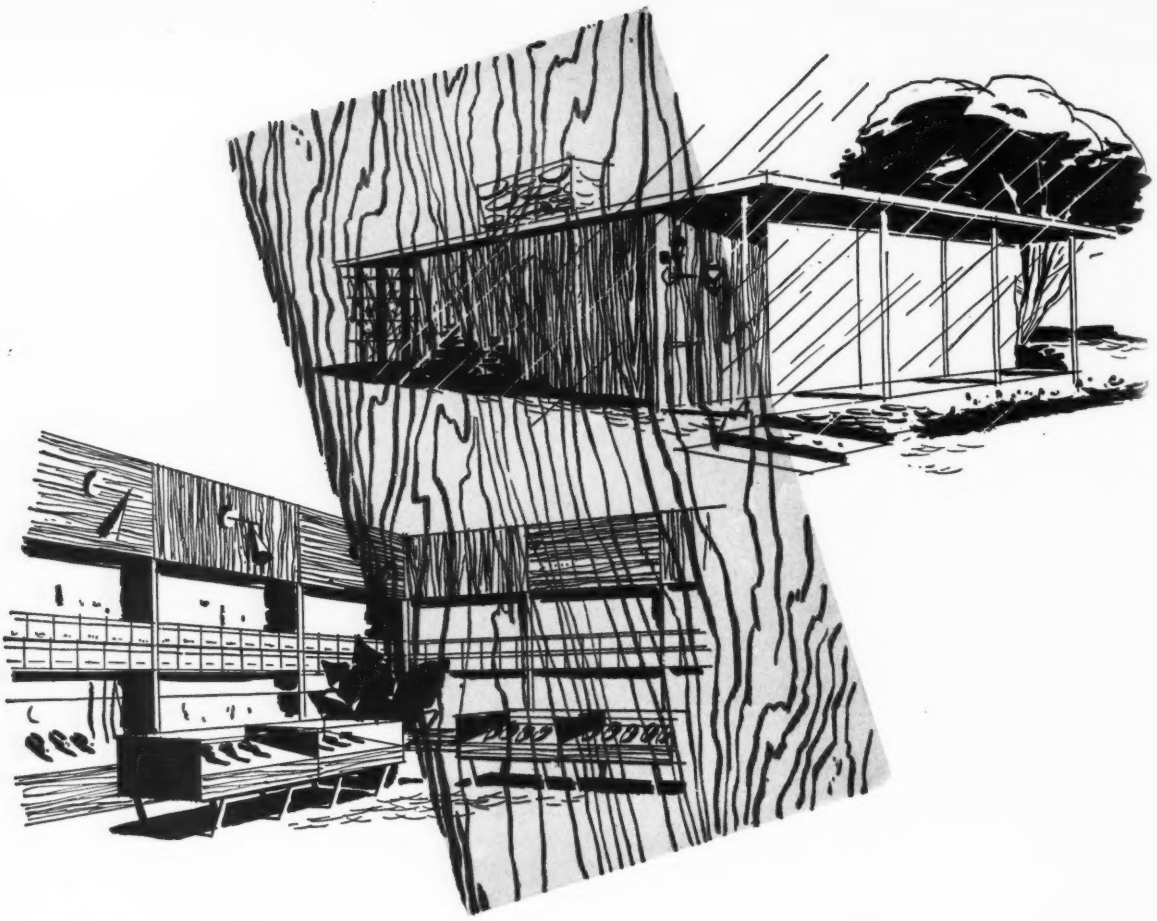

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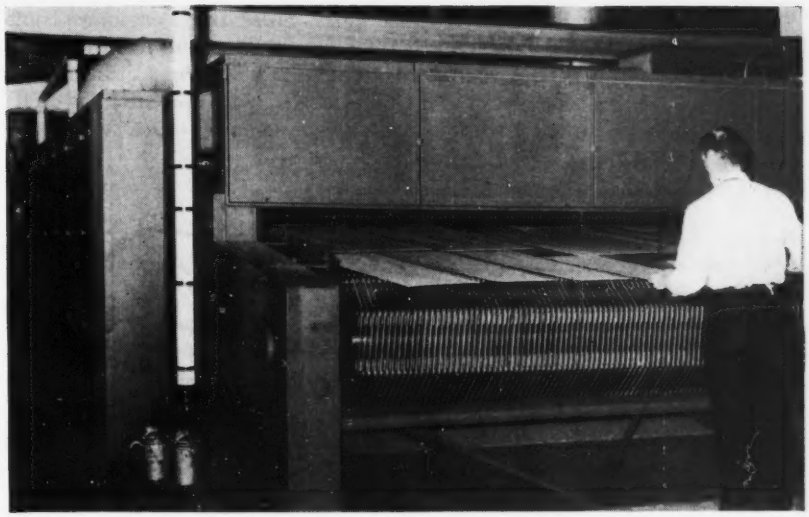

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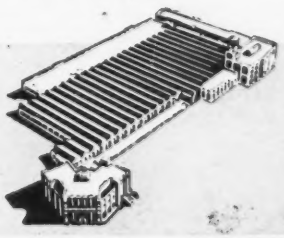

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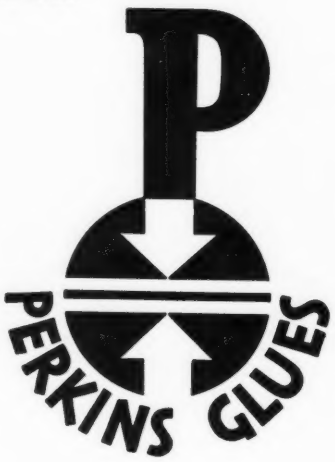

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Vol. III, No. 2 June, 1953

Growth of the FPRS—*A Guest Editorial*

AS RETIRING PRESIDENT, I would like to take this opportunity to tell you something about the growth of our Society and what I think this means to our industry. It has been my privilege to have been associated with the Forest Products Research Society since its organization on January 3, 1947. Therefore I have had an opportunity to observe the Society from its inception to the present time.

All of us have heard and chafed under the charges that the wood industry is not progressive. Of course, the reason that we have chafed under these charges is that there has been some measure of truth in them. However, I would like to submit to you that the growth of our Society during the past six and one-half years is all the proof that anyone needs that these charges cannot be laid to the whole industry or to all of the people associated with the industry. It is significant that in our Society over 2300 people are actively working together and supporting an organization devoted solely to promoting research and progress in the forest products industries. I submit as a statement of fact that anyone who did not wish to learn, to grow, and to change would not be a member of the Forest Products Research Society. A look at our membership roll and at the people and organizations represented in the Society is heartening indeed. We are not made up of, or supported by, a small segment of the industry. Instead, we represent an impressive and potent force in promoting the growth of the industry.

Early in the discussions about the formation of this Society, the question of who should and who would join such an organization kept arising. Would it be the technical men in the lumber, plywood, furniture, and related industries? Would it be those engaged in research, in government association and industry laboratories? Would it be those in forestry schools promoting and teaching wood utilization? Would it include industry leaders in management, production, distribution and sales of wood products who recognize the need for research, for change, and for growth, and who want to promote it in both their own companies and in the industry? Obviously, the type of organization to be formed depended on what type of people would be interested in membership. Fortunately and wisely, it was decided that if the organization was to do the job which needed to be done, it would have to serve all of the groups mentioned. So it had to be an organization that would interest and serve the purpose of not only the technical and research people in the industry but of plant operators, production managers, salesmen, and all of management up to the top.

Having decided then what the organization should be, the question of what to call it proved to be a complex and difficult one. Many names were suggested and discussed. Finally the list was narrowed down to two—the Forest Products Society and the Forest Products Research Society. I will not debate at this stage whether the best of the two was chosen. Frankly, I don't profess to know the answer. I do, however, remember some of the discussion. One argument was that the inclusion of the word "research" would make the Society sound too much like a professional society for laboratory people. Others argued that if the word "research" is taken in its broadest sense—that is, the search for and application of new knowledge in the production, utilization, and distribution of forest products—it does properly describe the Society and its activities. It was pointed out that research, in its broadest sense, is not limited to the laboratory. Rather, it is an attitude, a way of life, a desire to acquire new knowledge, and to use this knowledge to effect changes and make improvements in our forest products processes and products. If this is so, then it is important that everyone concerned with the future of our industry should be and must be interested in research. So on that basis, the Forest Products Research Society name was chosen and on that basis, membership solicitation has been made.

Some of our members still feel, and perhaps rightly so, that an unfortunate choice in names was made. I am inclined to believe that the actual choice of a name has made little difference one way or the other. I don't believe I have ever heard of anyone choosing to join the Lions Club in preference to the Rotary Club, or the Presbyterian Church in preference to the Methodist Church, because they thought the name more properly described the activities or principles of the organization. I believe that what an organization stands for and what it does counts for a great deal more than what it is called. I believe that our Society has grown and attracted the support of industry leaders because its objectives were sound and its activities have been those which they wished to support.

The growth of the Forest Products Research Society to date and its growth in the future will be because there are those in the industry who want to learn, to change, and to grow. As long as we have that, we will have a strong society and a strong industry. I would like to emphasize one more point however. The strength and growth of the Society will depend entirely on the interest and activity of its members. Just like all other organizations made up of people, what comes out of the Society will depend entirely on what its members put into it. If, as a member, you are putting in only $15 per year, you may be assured that you are getting your money's worth. You are receiving at least $15 per year in the cost of the publications alone. There is, however, potentially much more that you can get out of the Society, but the only way you can do this is by putting some more of yourself into it. You can do this by attending meetings both local and national, by taking part in programs and by working on a national, sectional, or local level to make the Society grow and to make it do the things you think it should be doing. Just as with all other organizations, the members of the Forest Products Research Society will get back out of the Society just what they put in—no more and no less. The growth of the Society to its present stature in six and one-half years has been heartening indeed. Its growth in the future, as in the past, will be an accurate measure of our faith in the future of our industry.

Ken G. Chesley

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The Utilization of Wood Waste in Eastern Canada[1]

J. H. JENKINS

Chief, Forest Products Laboratory Division, Department of Resources and Development, Ottawa, Canada

The many complex problems of wood waste utilization are closely coupled to the economics of production and distribution. Full utilization depends largely on the demand for primary forest products and for the goods resulting from manufacture of the incidental waste. Within these limits much progress has been made. Research continually adds to the data and processing experience to make possible more complete utilization as time goes on.

CONVERSION OF THE standing tree into sawlogs, poles, piling, railway sleepers or pulpwood results in wood waste which varies in volume and value according to the species cut and the method of logging. Some waste, such as tree branches and tops, is unavoidable; much, however, is unnecessary, as for example, high stumps, unnecessarily large tops, broken logs resulting from careless felling, merchantable material overlooked by the skidders, and so forth.

Waste is only a relative term and too often it is used loosely. Material which is discarded as economically impracticable to use in some places may, at other points where supply and demand are quite different, be considered valuable material. The situation differs markedly in different parts of Canada.

All down the line of waste, from the woods to the finished product there are fine distinctions as to what is and what is not wasted wood volume. For example, surplus sawdust produced because of excessive kerf or poor tooth form is preventable waste. However, sawdust unused owing to lack of economic outlet is unavoidable waste, though at any time in the future conditions might so change as to alter this classification.

In Canada, some 7,000 sawmills produce almost six billion feet board measure of lumber annually; 100 pulpmills use 9½ million cords of pulpwood to produce 7¼ million tons of pulp, and 500 million square feet of plywood come from some 45 veneer plants. To this must be added the large annual output of timber used in the round for posts, piling, and mine timbers. Thus, production on this scale requires the conversion of a great mass of material from the forests, with the incidence of a correspondingly high quantity of waste.

[1] Presented at meeting of the Forest Products Research Society, Eastern Canadian Section, March 5-6, 1953, at Toronto, Ont.

In any discussion on waste utilization it is well to remember that material can only be salvaged where the sale of the end product will permit recovery of something above the actual expenditures necessary to recovery and processing.

There is an increasing awareness by industry of the availability of these large quantities of wood substance. As a result, where utilization is comparatively low, it is often because economic methods of processing have not been developed, or profitable markets are lacking for such goods as can be satisfactorily produced.

Present Utilization Practice

In Eastern Canada pine, spruce and balsam fir are the principal softwood species cut. The two main commercial species of hardwood are yellow birch and sugar maple, of which some 300 million board feet are produced annually. In recent years increasing quantities of poplar have also been sawn to lumber.

There are about a thousand sawmills in the Prairie Provinces and some 4,300 in Eastern Canada. A number of mills in Eastern Canada have a production capacity of 150 thousand board feet daily, and 40 mills produce more than 5 million board feet per year, but the bulk of the mills are small.

Generally the operating season varies from two to three weeks in small custom mills with an annual output of 25 to 50 thousand feet board measure, to from eight to ten months in the largest mills. The production period for the bulk of the mills is from three to eight months. In recent years a few large mills have had no seasonal shutdown. Steaming or "bubbling" the mill pond generally prevented ice formation and permitted free loading at the jack ladder.

In the pulp industry, the number of tree species used as pulpwood is increasing and more poplar is being used in the manufacture of newsprint. In 1952 a company was organized in Northern Ontario to ensure that logging products are channeled to the use for which they are best suited: pulpwood moves to the pulpmills, sawlogs to sawmills, and trees best suited for poles and posts are diverted to that purpose.

During the past decade, there has been a very marked increase in the production of hardwood plywood in Eastern Canada. A plywood mill produces poplar plywood in the Prairie Provinces, and another is nearing completion. There are 33 plants (1951) in Eastern Canada, many of which have been recently modernized and expanded. Yellow birch is the main species used for veneer and plywood, and small quantities of maple, elm, basswood, and poplar are also produced. Three mills cut figured veneer from imported logs of walnut, mahogany, and other exotic woods. In Eastern Canada, the ravages of the "birch dieback", which attacks both yellow and white birch, has forced one plant to move from the Maritimes to Ontario. No softwood species are at present cut to veneer in Eastern Canada.

Two plants in Eastern Canada produce hardboards and three manufacture softboards. Two other boards do not fall in either of these categories but are of intermediate hardness. These are produced from planer shavings and a synthetic resin binder by companies established in the Maritime Provinces and in Newfoundland. This brings to seven the plants in Eastern Canada producing wallboards from waste.

Logging

A large proportion of the sawlogs and pulpwood in Eastern Canada is river driven to the mills. This is particularly so in the case of large and medium-sized sawmills, as most of the land-transported logs are received at the smaller mills. Sinkage losses as high as nine per cent may occur on long river-drives. Distance remains a handicap to better utilization and, therefore, considerable small material and trees of secondary species are left on logged areas because of their low floatability.

Studies made by the Ottawa Forest Products Laboratory on selected sawlog operations in Ontario, Quebec, and the Maritime Provinces, indicated that the four principal sources of logging waste are wood left in the form of: (a) high stumps; (b) long-butts, including felled trees left on the ground; (c) sound wood left in uncut defective trees of merchantable diameter; and (d) merchantable wood left in large tops.

The results of these studies indicate that more than twice the volume of merchantable wood is left in the form of large tops than from the other three sources combined. Nearly 19 percent (18.2) of the merchantable volume of the stand was left as waste after logging. Approximately 13 percent represents the waste contained in large tops. There remained after logging, from stands averaging about 2,300 cubic feet per acre, 430 cubic feet per acre of merchantable wood material.

Considerable variation was noted in the amount of waste found on different operations. This often occurred where similar stands were being logged. Wood volume left on logged areas varied from a minimum of 6 percent to a maximum of 33 percent. This variation between different operations indicates that overall waste could be materially reduced. It is significant to note that where low waste percentages were recorded the trend is towards integrated logging.

There has been progress in the recovery of top material for pulpwood. Some sawlog companies are extracting top material, unsuited for sawlogs, and sending it to pulpmills. Tree-length skidding favors the utilization of tops. The use of mechanical equipment, under certain conditions, is practical in Eastern Canada, and at least one company is skidding tree lengths with horses. In addition, the introduction of power saws has helped in reducing losses caused by high stumps and long-butting.

Hardwood veneer log operations present a special problem as only the best of the tree is selected and the tree portion unsuitable for veneer is high. At least one company in Eastern Canada is conducting experiments on the re-logging of areas following the removal of veneer logs, in order to increase utilization and improve the residual stand.

Lumber Manufacturing

Sawmilling has undergone many changes and modifications. In the early days virgin forests, close to centres of population, contained enormous quantities of large-size, high-grade saw material. Today a high proportion of the annual cut is from sawlogs of small diameter, and many new problems related to efficient conversion require intensive research. There has also been a marked improvement in the machinery and equipment available and sawmilling practices have necessarily undergone considerable change.

Studies have been made by the Ottawa Forest Products Laboratory at a number of representative sawmills in Ontario, Quebec, and the Maritime Provinces, to determine the effect of such variables as log size and mill machinery, on the manufacture of the lumber and the form and volume of the "mill waste".*

Table 1 shows the average volume of lumber and waste produced from softwood and hardwood logs.

The band mills produced from 10 to 15 percent more lumber per log than did the circular mills, an increase equal to from 5 to 7 percent of the log volume. The difference in saw kerf ($\frac{9}{32}$ inch for the circular headsaws and $\frac{5}{32}$ inch for the band headsaws) largely accounted for this difference.

Table 1—PERCENTAGE OF THE LOG VOLUME CONVERTED INTO LUMBER, SLABS AND EDGINGS, TRIM, AND SAWDUST

Products	Softwood Logs	Hardwood Logs
	Per cent	
Lumber	50.5	48.7
Slabs and Edgings	29.9	31.8
Trim	4.0	3.5
Sawdust	15.6	16.0

The percentage of the log volume sawn into lumber from spruce, jack pine, and balsam fir logs, under similar conditions, was the same, but there was considerable difference between those volumes and the ones from white pine or hardwood logs. In general, a higher percentage of lumber was sawn from spruce logs than from white pine and more from white pine than from hardwood logs of equal size.

Of the "mill waste" produced at the mills studied, some 50 percent of the sawdust was used as fuel by the producing mills, and a very small volume was sold for packing material. Utilization of sawdust for fuel was partially dependent on the type of mill. Small mills, depending to a large extent on gasoline engines, diesel motors, or wood-burning boilers for power, use little sawdust. The reverse held true for the larger mills, which, because of their permanence, find it economical to construct dutch ovens.

Some six percent of the slabs, edgings, and trim was converted into by-products such as lath, pickets, boxboards, basket bottoms, and furniture squares, and approximately 60 percent was used or sold for fuel. Utilization of slabs, edgings, and trim is also partially dependent on mill type, in that a large percentage of the smaller mills use the old, locomotive type, wood-fired boiler, and burn such material. The use of sawdust for fuel at the mills is generally a better utilization practice than the use of slabs, edgings, and trim, as the latter can often be sold as fuel, while (except in the case of a few suitably located mills) it is almost impossible at present to dispose of large quantities of sawdust in Eastern Canada.

The location of mills has an important bearing on the utilization of waste. When situated in or near towns or villages, mills are usually able to find a market for fuelwood. Mills at a distance from settlements often find that handling and transportation costs of this low-grade by-product make its disposal uneconomical. Eight mills situated at from 10 to 25 miles from a village disposed of only 16 percent of their slabs, edgings, and trim, as compared to an average of 78 percent for mills located less than 10 miles from a village.

Utilization Trend

Throughout Canada, sawmill efficiency and reduction of waste have been given impetus by the increasing cost of logs and the firm and attractive markets for lumber. At least three additional gang-mills have been put into operation in Eastern Canada in recent years, and another three in the Prairie Provinces. This type of mill appears to be especially suited to the manufacture of softwood lumber from small logs and where grade recovery is not of prime importance. These units reduce saw-kerf losses and effect additional savings by producing more accurately sawn lumber.

Rubber-tired, truly portable sawmills are now receiving attention and several sawmill machinery manufacturers in the U. S. A. are now making this type of mill. Their chief advantage is that they may be set up and taken down very quickly, and their high mobility enables them to be moved over woods roads.

Present methods of waste utilization have been briefly indicated earlier in this paper. In general, the greater advances in wood waste utilization have resulted from the integration of production. Wood material of suitable species is sorted on the basis of best use. Logs of a size and quality best suited for manufacture into veneer or lumber are so manufactured, while the

* Reported in detail in Forestry Branch Bulletin 99 "Factors Influencing the Manufacture of Sawlogs Into Lumber in Eastern Canada." G. E. Bell—1951.

small top logs and the mill waste from the sawlogs are utilized in the manufacture of pulp.

Pulp Chips

In recent years there has been a large increase in the volume of sawmill waste utilized as pulpwood. The high cost of pulpwood—as much as $30 per cord in some areas—has given an added impetus to this form of utilization.

In some cases waste wood is converted to chips at the sawmills, while in others the slabwood is shipped to a pulp-mill. For regions adjoining the ocean or large lakes, water transportation provides an economical method of moving wood waste, either as rafts of logging-salvage material, or in barges or scows. Barges loaded with pulp chips are now towed distances up to 300 miles. Transportation by truck or by rail is more expensive, and it is estimated that from 60 to 70 miles is the economic limit for pulp chips, and about half that distance for solid waste transported by truck.

Whole-log or slab hydraulic barkers and chippers have been installed at the larger mills on the Pacific Coast. No hydraulic barkers are used in Eastern Canada, but three mills are debarking logs prior to sawing. Two of these use a whole-log friction barker, designed in Canada. In the third mill a whole-log barker developed in Sweden has been installed. The buzz barker, with a cutter head similar to that of the buzz planer, is the slab barker in general use in Eastern Canada. Production from these machines, operated by two men, is approximately five cords per day.

For the better pulps the wood must be free of bark. It has been found advantageous to remove the bark from sawlogs before they are converted to lumber as this results in an increase in the amount of pulpwood available. It has been estimated that when a slab barker is used .4 units (200 cu. ft.) of chips are produced per thousand feet log scale. When a whole-log barker is used the production of chips increases to .6 units per thousand.

Species sawn, mill location, means of transportation, and production volume are the controlling factors to a continuing increase in the production of pulp chips from suitable wood waste. Progress in this phase of utilization, however, is reflected in the 200,000 units (200 cu. ft.) produced in British Columbia during 1950, and 50,000 cords of slabwood diverted to this purpose in Eastern Canada in the same year. This represents a marked increase in the volume utilized for this purpose in the past three years.

Development of a spreader stoker has made it practical to burn hogged fuel industrially. One mine in Northern Ontario used 18,000 tons of chipped wood waste as fuel during the first year of operation, at a reported saving of some $20,000 over coal.

Seven plants in Canada produce the Pres-to-log type of briquettes, while another, recently established in Ontario, produces smaller briquettes which are suitable for stoker fuel.

Tests undertaken by the Ottawa Forest Products Laboratory have shown that sawdust is suitable as a fuel for domestic heating in Eastern Canada and that sawdust of all the species tested could be burned satisfactorily either dry, or in the wet condition as produced by most sawmills. Maple and birch sawdust is a better fuel than spruce and balsam fir or white pine.

The only limiting factor in the use of sawdust as a fuel is the supply. For this reason, suppliers of this fuel should accept only the number of customers to whom sawdust deliveries could be maintained throughout the heating season. However, if a steady supply could be arranged or alternately, if a winter's supply could be stored under cover, sawdust would provide a suitable fuel for domestic heating in Eastern Canada.

Chemical Conversion

In the field of chemical conversion, progress continues in the development of efficient processes. Hydrolysis or saccharification of wood as a means of producing molasses for animal feed offers possibilities for large scale conversion of wood waste, although developments along this line are largely dependent on economic considerations. It is difficult to forecast industrial developments resulting from chemical processes, but it appears reasonable that present knowledge of the chemistry of wood, and continued research aimed at practical applications, may result in the creation of a demand for important quantities of waste wood.

Quantity production of tannin from certain barks is technically feasible, but it has yet to surmount the economic difficulties of competition with production from other raw materials.

Research

The importance of better utilization is fully realized in the planning of research where the fundamental values of wood substance now unused is under constant investigation. There has been increased appreciation of the complexities and vastness of the problems involved, and many of the research activities have been co-ordinated and organized on much broader lines. Co-ordinating committees have been formed and their membership includes representatives from Government and from industry.

Certain of these co-ordinating committees are organized by provincial bodies such as the Ontario Research Council. Their aim is to ensure that the many and diversified problems of wood utilization in their respective provinces are adequately studied, and that the most effective use is made of available research facilities, Federal and Provincial.

In the waste utilization field, the Forest Products Laboratories Division accepted the task of organizing a "Research Co-ordinating Committee on the Utilization of Sawmill Waste for Pulpwood". Problems involved in the conversion of solid mill waste to pulp chips have been reviewed and available data have been studied by the Committee. It was decided that more detailed investigation was necessary to secure fuller information on barking, chipping, and transportation, and studies to these ends were undertaken by the F.P.L.D. and are now in progress. In addition many of the activities of the Ottawa and Vancouver Laboratories of the F.P.L.D. are specifically concerned with waste reduction and utilization.

Discussion

In answer to a question from the floor Col. Jenkins reviewed recent developments with regard to improved utilization. In summary these are, formation of standards for pulp chips and the work being conducted toward improved saw design and towards improved logging and milling techniques.

"Back of our plants, back of the people who build and operate them, are our research laboratories, and they are perhaps our greatest single resource. Every new product, every improvement in process, every advance in technology, had its beginning somewhere, somehow, in the mind of a research worker in his laboratory. Research is the essential vitamin without which the body of industry loses its vitality and dynamic character."—Crawford H. Greenewalt, president, E. I. du Pont de Nemours & Co.

Forest Research and its Relation to the Wood-Using Industries in the Southeast[1]

E. L. DEMMON

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Among current and anticipated research problems in the Southeast are: finding uses for low grade hardwoods, developing and growing new better kinds of trees, and studying effects of forestry practices on water supply. There is promise that lower grade hardwoods will be the basis for new industries as time goes on.

THE FIVE SOUTHEASTERN STATES from Virginia to Florida comprise the territory of the Southeastern Forest Experiment Station and make up a very sizeable portion of the Nation's forest wealth. One-fifth of the Nation's commercial forest area is in these states (86 million acres). Forest industries of the Southeast number about 13,000 sawmills, 31 pulp mills, and more than a thousand secondary wood-using plants. No region in the country has such a diversity of forest industries, ranging from large pulp and paper and furniture plants down to small box and handle factories.

Since 1921, with headquarters in Asheville, N. C., our Station has been carrying on research on the forestry problems of this area. To the extent of the resources available, it has tackled the more important problems of silviculture and management, protection, utilization, and the economics of forest land use.

In the early twenties, the Station staff numbered only four men, including its first director, E. H. Frothingham. In those days bulk of the Station's work was devoted to a systematic collection of basic information needed to determine good forest management practices in the southern Appalachian region. Its early studies were concerned to a considerable extent with the seeding, growth, management, and uses of yellow-poplar and southern white cedar, and the factors controlling germination and early survival of the better oaks.

Comprehensive Survey

In a broad regional forestry program information was needed on forest management for the principal forest types, for better fire protection, watershed management, and for a comprehensive forest survey of the region. Work along these lines got under way during the period between 1927 and 1941. During that time considerable effort went into studies of timber cutting methods; that is, methods that would be of practical application, yet leave the forest in shape for improved growth and natural regeneration. Volume tables were developed for all the important mountain tree species.

Perhaps of equal or more importance to the wood-users and owners of forest land, a comprehensive forest survey was begun in this region in 1933. Prior to that time there was no reliable information as to forest acreage, timber and cordwood volumes, and current timber growth for the region. The first survey was completed for the region in 1940.

The uses for forest survey data seem endless. Pulp and paper companies and wood-using concerns of all kinds have drawn upon the survey for basic information to be used in planning the location of plants, the procurement of raw materials, and acquisition of forest land. The need for such information was clearly illustrated by the inadequacy of previous rough estimates. In North Carolina, for example, it was found that the acreage of forest land was actually somewhat less than shown in previous estimates, but the volume of saw timber was found to be more than twice as great, and the number of operating mills over three times that previously reported. Errors of this magnitude are incompatible with sound industrial planning and policy formation on either a local, State, or national level.

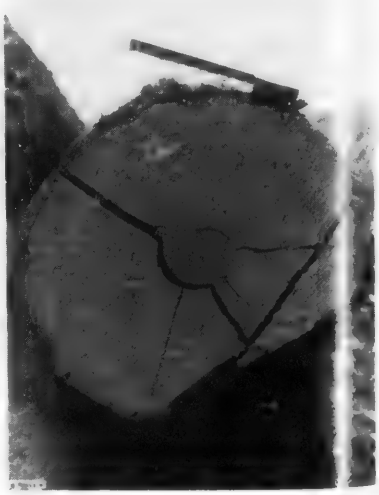
The importance of studies of the relation of forest cover to stream flow, erosion and watershed management was early recognized by the Station. It wasn't until 1931, however, that funds were made available to initiate such studies.

The war and post-war years brought additional duties and functions to the Station. Within a week after the declaration of war, the Station began to conver from a strictly research to a war-service agency. A trained staff was placed on War Production Board surveys to determine the quantity and availability of various defense materials. While these numerous war jobs were under way, only a minimum of records were continued on the Station's long-time experiments in forest and watershed management.

Current Operations

Let me review briefly how the Station operates currently. Its field studies are concentrated at eight research centers located in various parts of its territory. Each center was selected as typical of the forest conditions in a section, so that the findings are applicable widely, to broad forest types.

Much of the Station's program is carried out in cooperation with State forestry departments, with schools of forestry, and with the forest industries. Its program at the various



Hickory trees are plentiful, but internal stresses often cause severe splitting the logs. Problem is under study.

[1] Presented at meeting of Forest Products Research Society, Carolinas-Chesapeake Section, November 7, 1952, at Raleigh, N. C.

An automatic wood burning furnace for curing tobacco is a direct result of work of the Forest Utilization Service. This provides a profitable outlet for low grade thinnings on the farm.

Poor piling such as this results in warped, cupped, split, and stained lumber. Seasoning studies, publications, and courses are improving this situation.

centers is reviewed periodically by advisory councils made up of local forest landowners, technicians, and forest users. The results of Station studies appear currently in station papers, technical notes, annual reports, Government bulletins, and in professional and trade journal articles. Its experimental forests serve as demonstration areas illustrating various types of forest management. The Station also works closely with forest pathologists, entomologists, and biologists from other bureaus.

The largest share of the Station's work is forest management research. In this field, the major single project is a long-time comparison of the forest management systems applicable to each major forest type. On each of six different experimental forests in various parts of the region, a great many 40-acre compartments have been designated on which are applied the major silvicultural systems, usually comparing two rotations, and two intensities of forest management: (1) for small-sized products such as pulpwood and (2) for large-sized products such as veneer logs and sawlogs. In addition to the long-time purposes for which they were set up, these compartments are invaluable in providing conditions for detailed studies of indivdual tree growth.

Problem of Low-Quality Hardwoods

There is perhaps no more important forestry problem in the Southeast than that created by the rapid encroachment of low-quality hardwoods into the more valuable pine stands of the Piedmont and Coastal Plain. The major research job here is to develop economical ways for controlling inferior hardwoods on pine sites. After testing numerous chemicals, concentrations, and dosages on different tree species by different methods and at various seasons of the year, Station men have worked out several practical poisoning techniques. Eventually, increased utilization of these poorer quality or slower growing hardwoods should help ease this problem, but in the meantime, timber growers can benefit from hardwood control measures.

The Station's fire research program has developed a system of fire danger measurement which is used at more than 600 fire danger stations from Maine to Texas. The data guide day-to-day fire control action and forewarn against a buildup of extremely hazardous conditions such as those that caused the Maine disaster in 1947. In many states the danger measurements are used to alert the public and close the woods: also to mobilize every fire fighting agency. Another fire study has to do with fire behavior, both of wild fires and in prescribed burning. Fire is now recognized as a valuable tool in the management of southern pines, and Station studies have helped work out details of its proper use.

There is no question that water has a commanding place in the economy of the entire Southeast. In many places the value of water far exceeds the total value of harvested timber and other wood products. Adequate supplies of good-qaulity water are essential to an expanding paper and rayon industry. Many municipalities are enlarging their watershed areas as a means of increasing their available water supplies, while sportsmen are demanding greater use of streams for recreational purposes. The Station's watershed investigations have been centered at the Coweeta Hydrologic Laboratory in Macon County, Western North Carolina, where a 5,600-acre has been set aside specifically for this type of research. The work done there has become internationally famous and serves as a guide to many projects in the field of water and soil conservation. It is showing that certain forestry and agricultural practices are harmful to sustained yields of good-quality water and is pointing out what can be done to remedy them.

Better Kinds of Trees

In addition to management problems that are dependent on proper utilization of our forests, we are now starting on a program of genetics or tree breeding that will produce the kinds and qualities of timber needed for particular products. The rate of growth and density of trees can be controlled by silvicultural practices, but we are now going further and seeking superior trees to propagate and breed. In the southern pines, for example, there appear to be many individual trees that grow faster than their neighbors. Such trees may have a high or low percentage of summerwood, and we are selecting out types of trees to breed which will produce a particular quality of wood. In such studies, we are working closely with the wood-using industries to determine the types of wood best suited to their various products. I might add that results from these studies should not be expected in the next year or two. This is a long-term proposition.

In the field of economics, a resurvey of the forest resources of Georgia and North Carolina is currently under way, in cooperation with State forestry organizations and with local industries. These resurveys are showing the forest

resource situation on a local basis, both as to timber volume and quality. For one thing we have found that timber quality has been declining and that now there are more cull trees, particularly hardwoods, in the forest than there were at the time of the previous survey 10 to 15 years before. Also, the amount of forest growing stock is found to be currently below that required to meet estimated future needs. This all points to the necessity for better fire protection, improved forest management practices, more complete utilization, and curtailment of waste, wherever possible.

Utilization

Another current Station project is an investigation of the feasibility of salvaging sawmill waste for use in the production of pulp, hardboard, chip-core panels, or other products for which it is suited. The area under study is a 30-mile-radius circle in the South Carolina Piedmont, where about 160 small sawmills are located. Within this area, a survey has been made to determine how much topwood, slabs, and edging strips of different kinds of wood are produced currently, where this waste wood is located, and in what concentrations. The next step will be to compare the costs of preparing, assembling, and transporting the various classes of waste material under alternative methods of operation.

Of particular interest to this group was the setting up of a Forest Utilization Service at the Station in 1945. This Service provides a liaison between the Forest Products Laboratory at Madison, Wisconsin, and the wood-using industries of the Southeast. Its objective is to promote better utilization of forest products in the broadest sense. Already it has accomplished much towards the improving of drying practices and in reducing waste, through organizing and conducting courses in several fields of wood utilization and by actual studies at individual plants.

The Forest Utilization Service project is carried on with a staff of but two men in this region, George Englerth and Walton Smith. These men, of course, draw heavily upon the Forest Products Laboratory for their basic information. Both have had considerable experience and training at the Laboratory and are well equipped to help the industry folks in this region. They keep up with all new developments at the Laboratory and when special circumstances arise, they enlist the services of Laboratory personnel, bringing them to this part of the country for expert advice and guidance. Not the least part of the Forest Utilization Service job, however, is to refer back to the Laboratory those unsolved forest utilization problems confronting industry here.

Other functions of the Forest Utilization Service are to pass along suggestions for needed research to State organizations and private agencies, as well as to the Laboratory, and to do a certain amount of research themselves, usually in cooperation with industry. Examples of the latter are studies of the causes of low utilization of hickory, the development of automatic wood-burning furnaces in the drying of tobacco, the use of improved wood products for picker sticks and shuttles in the cotton textile industry, the development of tree and log grades for veneer logs and bolts, and sawlogs, the improvement of seasoning practices in hardwood lumber, and numerous others.

The Southeast is blessed with an abundance of both pine and hardwoods. We have been best known for our southern pines, from the beginning of the naval stores industry in early Colonial times to the present insatiable "two-by-four" market. Pine is constantly in demand and will continue to be, primarily as a construction material, for lumber, and for containers, pulpwood, and many other purposes. We will plant it, manage it, and favor it in many places. Since the Station's research program has been largely concentrated on forest management of the pine types, we have learned a great deal about them. Of course, we will continue to study the pines. But in future utilization work in the Southeast, and in our entire forest research program, I feel that we must give more and more thought and attention to the hardwoods. Here is almost a new source of raw materials for the pulp and paper industry, for board mills, and for a wood chemical industry that few even have visualized as yet.

Southern Hardwoods

Whenever a forester or a lumberman begins to talk about hardwoods, each of us conjures up our own picture of hardwoods; a man from the Sandhills thinks of blackjack oak, a mountain man thinks of yellow-poplar, cherry, and oak, and out of a hundred people, there are likely to be 100 different mental pictures of what is meant by hardwood stands. And this is to be expected, for there are more than 50 commercial hardwoods in the Southeast and their combinations plus the non-commercial hardwoods add up to a varied picture.

Our forest economists tell us that, based on the forest survey, about 35 percent of the entire forest area of the Southeast is dominated by hardwoods (30 million acres), and that the proportion is on the increase. Hardwoods comprise 34 percent of the total merchantable saw-timber volume (52 billion board feet). However, when we consider total cubic-foot volume in both sound and cull trees, hardwoods account for 54 percent of the total (37 billion cubic feet). The proportion of cull trees among the softwoods makes up only 4 percent of the volume, whereas in the hardwoods it is 28 percent. This cull factor in hardwoods has increased in recent years, which is all the more reason to find uses for these trees which have so little market value at present, and which are interfering with the growth of the more valuable pines.

Hardwood Markets

There is an excellent market for quality hardwoods and this should continue indefinitely. The flooring industry will take all the good oak it can get and some that is not so good. For white oak of better than flooring quality, the stave buyers pay well. For yellow-poplar, there is a ready market at the furniture plants, which prefer poplar to any other species for core stock. The furniture industry also wants good quality gum in the form of veneer logs, squares, or boards. Also, sycamore, beech, hackberry, maple and many other hardwoods find their way into the furniture plants. Good grade hickory is always in demand for handle stock, ski stock, and for picker sticks. Dogwood for shuttles probably brings the highest price per cubic foot of any wood in the Southeast. I could list a dozen more hardwoods and their uses but I can anticipate your questions about what can we do with low-grade oak, wormy maple, upland sweetgum, heart hickory, etc.

What are we going to do with hardwoods riddled with heart rot, butt rot, and other defects? The scarlet oaks are notorious for hollow, rotten trunks. Many entire hardwood stands are high in cull. However, many foresters believe that under good forest management practices this might not hold true in the future. What would scarlet oak, gum, dogwood, and other hardwoods be like if they were never subjected to fire? What is the effect of stand density, or stand composition, on the growth rate? There are so many things about hardwoods that we do not know.

(Continued on page 85)

Knife Marks Per Inch[1,2]

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It is suggested that the number of knife marks per inch be made the basis for establishing quality standards for surfacing various wood products, just as moisture content is now established. Regardless of the type or number of cutters on the head, rate of feed would be adjusted to revolutions per minute to result in the number of knife marks per inch predetermined as standard for the product being surfaced. With such standards set, the operator could not then reduce feed rates to conceal other operating deficiencies such as an unbalanced cutterhead assembly. Conversely, rate of feed would be speeded up where the operator was running too many knife marks per inch for the given product.

WOODWORKING PRODUCTION as we know it today is, to a great extent, the result of individual initiative, imagination and effort. Knowledge has been gained through trial and error in the solution of each particular problem and improvement in production has often been confined to the ingenuity of each plant. The industry has had no handbook with ready answers, formulas, standardization tables and other facts such as constantly used for reference in the metal working industry; nor could it turn to the universities and colleges for graduates in woodworking engineering. Gradually this condition has changed and, although much is still to be done, we can see the results of various associations, societies and groups through the exchange of ideas and methods. Trade journals have been invaluable in the publishing of articles by competent and responsible writers and now a number of our larger colleges are including courses in the training of men for the woodworking industry. All this is progress towards standardization of methods.

Consider what has been accomplished in kiln drying. Because lumber can be brought to a definite moisture content, the user now specifies the percentages desired. It was not too long ago that hot-plate pressing was accepted in this country, more recently electronic gluing, and with it the ever constant improvement in glues. Stresses and strains for packaging can be determined from definite figures. Plant layouts, cutter-head and knife care, production methods are but a few of the phases that have benefited by written articles and group discussions. It is just such activity and open-mindedness of the industry that gives me this opportunity to present a suggestion that pertains to the standardization of machine feed speeds. In this we seem to have one instance where the answer is still pretty much left to the machine operator and such costly guessing is worthy of serious consideration.

Maximum production from moulders, matchers and surfacers is the result of obtaining an acceptable machine finish on stock at the fastest possible feed speed. It is not so difficult to produce an acceptable machine finish but the problem is to produce it without sacrificing feed speed. How often the operator has said, "I couldn't get a good finish at 125 feet per minute so I had to slow down to 100 feet." Why couldn't he get a good finish at 125 feet? Perhaps under perfect conditions top speed should have been 150 feet per minute but how can you prove it to the operator? This difference at 25 feet per minute in speed amounts to 1500 lineal feet per hour or 12,000 lineal feet per eight hour day. At eighty percent efficiency this would be 10,000 lineal feet of material lost every eight hour shift. Multiply this by a number of machines or a greater loss of feed speed and we have a problem that certainly deserves a solution.

Many factors enter into the machined finish of a piece of lumber. The number of knives in the cutterhead, the cutting angle of the knives, moisture content, spindle speed, the conditions of the machine, knife jointing, type of material and others including the human element, each of which deserves individual attention. In trying to bring order out of chaos, it would seem practical to base the results on the controlled factor of spindle speeds and feed speeds in relation to knives in the cutterhead which would be knife marks per inch.

The end use of the material being run determines the class of finish required. Obviously such stock as shiplap, siding, sheathing, and similar concealed or outside stock does not demand the type of finish required on interior trim and millwork, sash, doors, or flooring, and cabinet work and furniture are in a still higher bracket. It would seem that, in each case, the class of finish should be determined by the minimum numbers of knife marks per inch that would produce an acceptable finish. Once worked out such a table would serve as a standard of efficiency set up for the type of machine being operated. Whether running at 7200 RPM with one knife cutting or at 3600 RPM with eight jointed knives, the table of knife marks per inch for an acceptable finish would remain the same. How would this work out in running sash stock from any of the soft woods generally used? Assume that 12 knife marks per inch have been determined as the minimum number possible for an acceptable finish on this type of stock. For the purpose of comparison, we will use the normal spindle speed of 3600 RPM without considering load loss and will use the formula. Knife marks per inch equals number of knives times revolutions per minute divided by inches per minute.

Therefore if 12 knife marks per inch are desired a four knife head at 3600 RPM should be run at a speed of 100 feet (1200 inches) per minute, a six knife head 150 feet per minute and an eight knife head 200 feet per minute. At 6000 RPM with one knife in the cut, the feed would be approximately 41 feet per minute, at 7200 RPM 50 feet per minute and at 9000 RPM approximately 62 feet per minute.

Make Proper Corrections

It is not, however, as simple as that. The machine is set at the correct feed speed and 12 knife marks per inch are being produced but the finish is far from perfect. It might be tearing or fluttering or loping or sniping and it just isn't good. Here is where there

[1] Presented at meeting of Forest Products Research Society, Northern California Section, October 31, 1952, Sacramento, Calif.
[2] Presented by James Rowney, Rowney Machinery Co., Oakland, Calif.

is a tendency on the part of the operator to slow down the feed of the machine to get the knife marks closer together and minimize the defects. But it is recognized that 12 knife marks are enough under perfect conditions and therefore, instead of covering up by cutting the feed speed the operator should try to make the corrections at the points that are causing the difficulty.

Possibly the cutting angle of the knives is not correct. This should be studied and through tests or inquiry, rectified as quickly as possible. Perhaps there is a bad bearing on the spindle that is setting up a vibration reflected on the stock. There might be a misalignment in the machine somewhere, too wide a gap between the chipbreaker and the pressure bar and any number of other reasons most of which are probably known to the operator and can be corrected without difficulty. Especially if he knows that he has to show good work at 12 knife marks per inch. True, this cannot all be done at once but with the cooperation of the men on the job it can be worked out in a reasonable length of time.

Cutting Angles

I have been discussing the running of sash stock of similar characteristics but in other branches of the industry, variation in texture and density present added problems. Nevertheless, knife marks per inch can still determine the acceptable finish. In cabinet work this may be 18 or 20 but the minimum number is always a constant figure. With the variations in woods, cutting angles become the most difficult to solve and it cannot be expected that the mill owners perform all the research necessary. It is, however, quite possible that an institution such as Forest Products Laboratory will sometime in the near future present the industry with this valuable information. They could run tests in a scientific manner considering texture, density, moisture content and knife approach. Cutting angles and power consumption are, at the present being analyzed at one of our larger universities and machine and cutterhead manufacturers are earnestly endeavoring to correct answers to these baffling questions. Correct cutting angles vary in accordance with the grain structure, density and moisture content of the material. Roughly speaking, soft woods can use a greater cutting angle than hard woods, but there are exceptions. Dry stock responds to short cutting angles but the characteristics of the material prevent the use of any general rule and each must be worked out separately.

Even in the event of a sanded finish, knife marks play an important part. A good machine finish minimizes the work of the sander, for a sander should be a polisher or smoothing machine rather than a surfacer. This is definitely reflected in paper costs and machine upkeep.

Perfect Balance Necessary

Unbalance of cutterheads is another very common cause for unsatisfactory machine finish and a comment at this time will explain how greatly a cutterhead can be affected by centrifugal force. In determining the pull in pounds of a cutter on a cutterhead, we would use the formula taking the weight of the knife in pounds, times the radius of the cutterhead in feet, times the revolutions per minute squared, times .000341. For example, a twelve ounce knife on a 6″ diameter cutterhead running at 3600 RPM would be .750 x .25 x 3600^2 x .000341 or 828.6 pounds pull; at 6000 RPM it would have 2301.7 pounds pull and at 7200 RPM 3314.5 pounds. From this you can see the necessity of perfect balance not only in the knives but the clamps, bolts and other removable parts. All of this pertains to static balance but mention should be made of dynamic balance. Cutterheads should come to the user perfectly balanced statically and dynamically, but the placing of cutters on these heads can create an unbalance. Therefore, in setting up a cutterhead, whether a square head with hand ground knives, or an eight knife head will milled cutters, it must be remembered that two knives of equal balance must be placed on opposite faces and in line of rotation with each other. In other words a ten ounce knife on end of an 8″ square head will not balance dynamically with another ten ounce knife placed on the opposite force at the other end of the head. Statically the head would be in balance but not dynamically and a noticeable vibration would be set up at operating speeds.

Green Lumber Problems

Wet or green lumber requires a keen knife edge at a long angle approach in order to sever the wet stringy grain. A short cutting angle has a tendency to push the grain ahead of the cutting edge that produces a pulling effect on the surface of the stock. This is also true with dull knives or knives with too great a joint. Furthermore, green or wet lumber has a springy consistency on the surface and unless the fibers are cut clean with a sharp knife, the knife edge depresses the material leaving a raised grain surface.

As the moisture content varies from green to kiln dried, the cutting angle of the knife should become more blunt. The fibers of dry stock do not have the clinging effect of green stock and a long cutting angle would lift the grain with a tearing out of the dry fibers. By using milled pattern cutters the pre-determined cutting angle can be developed and machined into the cutter, but in using hand ground knives in a square head for detail work it is sometimes necessary to slow down the feed to eliminate tearing at this great cutting angle.

A square head using a flat knife has a cutting angle of approximately forty degrees. This is usually all right for green lumber but much too much for kiln dried stock. This can very often be corrected by running the knife with the back or beveled side to the head instead of flat side. Shallow patterns can be ground into the cutting edge of the knife and deep patterns into the bevel. If this seems to have too short a cutting angle, possibly eight or ten degrees, this can be increased by grinding a longer bevel on the knife.

Lack of Information

Round heads, of course, at manufactured to position a knife at the required cutting angle. Where wet or green lumber predominates, the head is furnished with knives cutting at a twenty-five or even thirty degree cutting angle, while for reworking kiln dried stock fifteen to twenty degrees would be most satisfactory.

It has been previously mentioned that so many variations enter into the selections of correct cutting angles that it is difficult to treat the subject in anything but a general manner. Here again, we find available material lacking, and it becomes necessary to more or less use the trial and error method to arrive at the correct answer for each particular type of wood and moisture content.

It is the amount of acceptable material coming out of the back end of the machine that determines high or low production, and therefore, good finish at the highest possible feed speed is a vitally important matter. Previously I have mentioned that a slow down on one machine of only 25 feet per minute meant a loss of approximately 10,000 lineal feet in an eight hour day. Check up what this means in your plant and you might be surprised at the possibilities for correction. Once

(Continued on page 85)

Knife Cutting Problems[1]

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The art of machining wood must become the science of machining in order to effectively reduce the cost of manufacturing wood products. Torn grain, raised grain, chipped grain and fuzzy grain are generally accepted as defects that are inevitable when wood is cut with saws and knives. Some progress has been made in recent years in reducing machining defects through the use of high cutter speeds made possible by the introduction of frictionless bearings and the development of high-speed steel, case alloy and cemented-carbide cutters. However, "the art" will not become "the science" until basic facts are accumulated concerning the relationships between the cutting edges of tools and the characteristics of the materials being cut. In addition, a great deal must be learned about the nature and magnitude of the forces that exist between the cutters and the materials being machined. Paper discusses some of the problems of knife cutting and the progress that has been made toward their solution.

THE PROBLEM of machining wood may be divided into three interrelated considerations.

1. Characteristics of materials being cut
2. Mechanics of chip formation
3. Tool design and maintenance

Characteristics of Materials Being Cut

Woodworking tools are generally expected to function with equal efficiency on practically all non-metallic materials notably hardboard, insulating boards, and plastics as well as wood species of wide ranges of densities and grain directions. Obviously the same tool material, cutting edge design or cutting speeds and feed rates cannot be expected to work effectively for all those materials. Because of the magnitude of the problem, this paper will be confined entirely to the discussion of wood machining.

It is essential that the machining operations be considered in the light of the physical and mechanical properties of the various species of wood due to the large variances between species. This does not mean that knives need to be changed or completely reground with each change of species; the various commonly used species may be grouped according to their machining characteristics and then optimum knife designs and speeds and feed determined for each group. It is interesting to note that such a classification and recommended knife designs (cutting and clearance angles) was published[2] a number of years ago. Similar information has been prepared by other machinery manufacturers. Such empirical information upon which knife design is based has been of considerable value in the past, but for higher, more efficient production in the future, knife and cutterhead design must incorporate both experience and fundamental facts concerning machinability.

Probably the most significant characteristics of wood from the machining standpoint are: cellular structure and the orientation of the cell elements and physical and mechanical properties not only between species but also in the three principal axes, tangential, radial and longitudinal. The occurrence of spiral grain due to spiral growth of the tree and diagonal grain resulting from faulty sawmilling also affect machinability.

The cellular structure of wood with its thin cell walls makes cutting without tearing difficult if not impossible. Figure 1, shows the size of a shaper knife in approximate scale to the cellular elements of white pine (tangential section). A land of one-sixty-fourth of an inch is shown to illustrate the relatively large contact area between knife and workpiece resulting from what is generally considered light jointing. Obviously under such conditions true cutting is impossible; the action is one of splitting the cells apart, rather than cutting them. Such splitting will, of course, occur along the line of least resistance—parallel to the cellular elements. The bending of the wood elements as they are forced up the face of the knife causes the cells to buckle and crush. This is evidenced by the relationship between T_1 and T_2, and the length of the chips before and after cutting. Both the length and thickness are reduced appreciably and the chip is generally curled and continuous for the entire chip length. The surface that results from cutting as shown in figure 1 is usually good; the cellular elements on the generated surface are not severely crushed or torn. These conditions represent the ideal from the standpoint of the quality of a machined surface.

If the thickness of the chip, T_1, is increased to the point where T_1 and T_2, and the chip length before and after cutting are the same, then the cutting operation is not under complete control and the generated surface may or may not be acceptable depending on whether the knife is cutting with-the-grain or against-the-grain in combination with the advance of the workpiece per cut and the depth of cut. The chips under these conditions are splinters and are broken away from the surface rather than cut. Figures 2A and 2B show the effects of feed direction in relation to the rotation of the cutterhead and direction of grain on the quality of surface of a beach block. In production work each piece of stock cannot be examined in order to determine which way to feed it through a machine to avoid cutting against-the-grain. Further, the fiber direction frequently changes so that machining on the same piece may be with-the-grain in one area and against-the-grain in another. This is especially true around knots, swirls, or on lumber that has curly, fiddleback or wavy

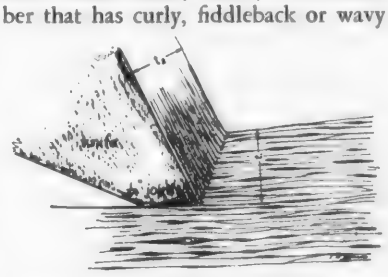

Figure 1.—Schematic diagram of a shaper knife making a cut along the grain of white pine. The sketch represents the formation of an "ideal" chip. A land of 1/64 of an inch is shown on the knife to represent light jointing.

[1] Presented at meeting of Forest Products Research Society, Northeast Section, December 4–5, 1952, New York City.

[2] By E. C. Atkins Co., Indianapolis, Ind.

Figure 2.—Relationships of grain direction, cutterhead and feed direction on the quality of surface produced. Left: Cutterhead rotation direction with the grain. Right: Cutting with the grain. Feed direction in both photographs opposite to cutterhead rotations.

grain. Mahogany and several other species present a serious grain direction problem because of alternating spiral grain. That growth condition makes it impossible to machine the wood with-the-grain especially on the radial surfaces because of the changing zones of cell orientation. Since the wood materials being surfaced cannot be oriented in production work so that the cutterhead rotation will be with-the-grain at all times, it is necessary that other measures be taken to prevent torn grain. Some methods of preventing or reducing the severity of torn grain will be mentioned in the discussion of chip formation.

End Grain Problems

Machining end grain, which must be done frequently in the shaping of wood parts, presents problems that can be attributed directly to the structure of wood. As the knife strikes the side surface of the wood cells, the cell walls yield by buckling because of their thinness and lack of support due to the cell cavities. The yielding of the cell walls continues until the cells are severed by the knife at the line of the generated surface, or in tension below the generated surface. If the cells are severed by the knife before they are badly deformed or torn apart, the resulting surface is usually good. Fuzzy grain results when the fiber bundles are displaced considerably before the knife cuts them; after the blade passes over the deflected fibers, the fibers straighten and appear as projections or fuzz above the principal surface. If, however, the cells fail in tension before they are severed by the knife, torn grain results. E. M. Davis (1) reported, in a study of the shaping of redwood conducted at the United States Forest Products Laboratory, that tear-outs occurred nearly four times as frequently in the flat-grain stock as in the vertical-grain specimens. These wood structure-machinability relationships apply to other species as well as redwood as observed in recent studies at the University of Michigan Wood Technology Laboratory. There is a need for establishing basic relationships between machinability and the physical and mechanical properties of wood. Some progress is being made at present but very slowly.

Reineke (2) in his research on sawing has made analyses of wood fiber severance with circular saws. That study led to the development of a circular saw design that incorporates two distinct tooth forms in one blade; chipper teeth to remove the major portion of kerf, and side dresser teeth to establish the smooth surfaces that are required for edge gluing of lumber directly from the rip saws. Drake, (3) several years ago, developed a saw blade that combines kerf removing teeth and knife-like side dressing cutters to achieve smooth surfaces for glue joints. Other investigations have improved designs by increasing saw stability through the use of thick-hub blades, and teeth with large top bevels to give shearing action to the cutting edges. The theory behind all these approaches is that the load on each tooth must be kept sufficiently small and equally distributed to eliminate plate vibration and tooth deflection. The same result may be achieved by making blades stiff enough to resist deflecting forces. The fact that numerous wood products manufacturers are successfully making glue joints without jointing after rip sawing, demonstrates that smooth surfaces can be obtained by sawing at feed rates that are acceptable for present-day production. Research and product development are paying off in better equipment and work of higher quality especially with the cemented carbide saws.

Knife-like cutters present problems somewhat different than saws do. It is not unusual to see rip saws with 30 or more teeth while cutterheads with more than 12 knives are infrequently used. The majority of cutterheads are under eight inches in diameter and consequently the peripheral speeds are lower than for sawing unless belt drives or high frequency converters are used to raise appreciably the cutting speeds of the spindles. In addition, machines using knife cutters are generally operated at higher feed speeds than saws. These facts contrive to make knife cutting less efficient than sawing.

A criterion that is widely used in industry for adjusting feed speeds to the rpm of the spindle and the number of knives in the cutterhead is the number of knife marks per inch that appear on the machined surface. This is similar to the system used in metal working where rates of feed are generally expressed as feed per tooth or feed per revolution. Knife marks per inch can be converted to feed per tooth by calculating the reciprocal of knife marks per inch, which can be obtained by dividing one by the number of knife marks per inch. Thus: 20 knife marks per inch is the same as .05 inch per knife. It is the opinion of the author that too much emphasis has been placed in the past on judging surface quality on the basis of knife marks per inch. Other factors such as the grain direction of the workpiece (which has already been discussed), diameter of cutterheads, feed speeds and the condition of the machine and knives are of equal importance. Petter, (4) in a very comprehensive analysis of knife marks, points out some fallacies of estimating surface quality by the knife marks per inch. The influences of those variables on surface quality can be studied most effectively by observing the action of a knife as it makes a cut, and by measuring the magnitude of the cutting forces involved.

Mechanics of Chip Formation

An analysis of the cutting action of rotating knives should shed some light on the mechanics of chip formation and the relationship of chip formation to surface quality. Previous research on this subject has dealt with static

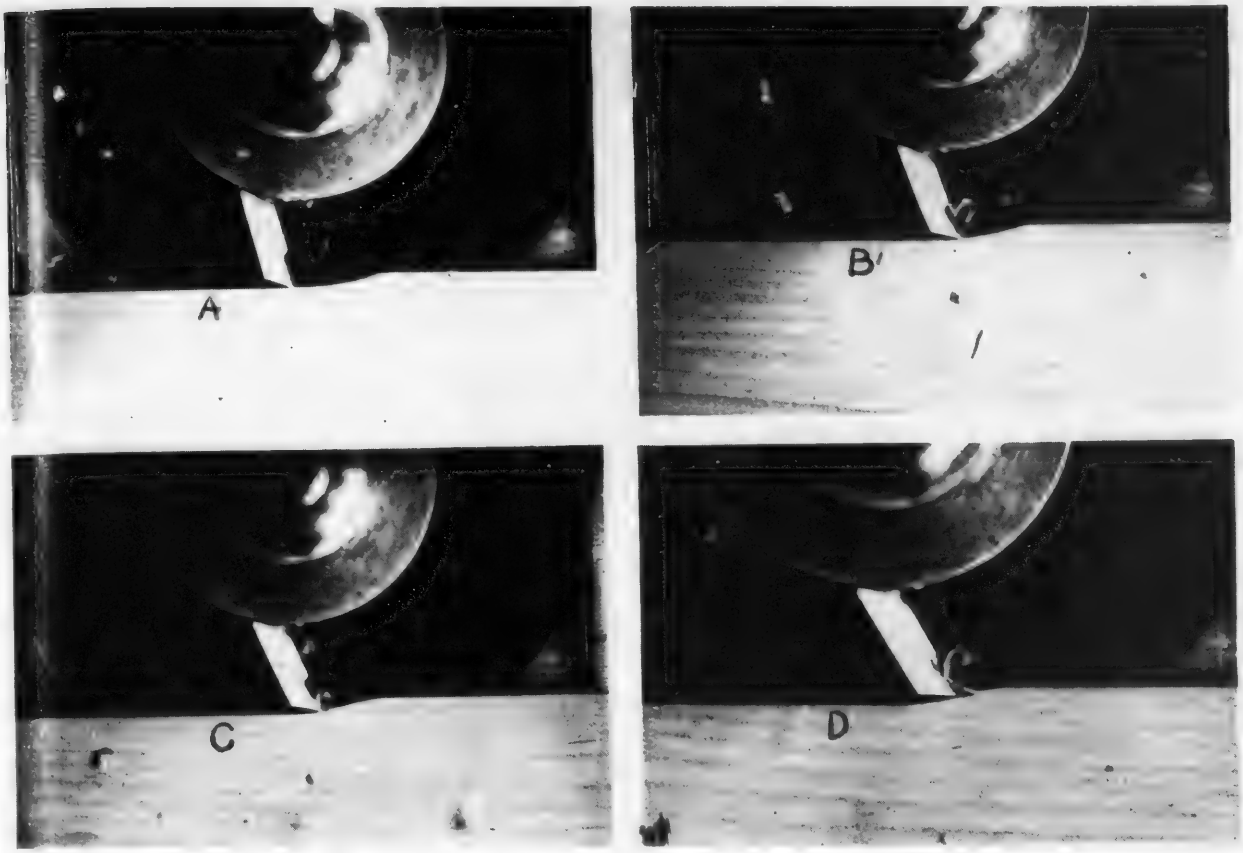

Figure 3.—Photographs of a shaper knife in action. Four inch cutting circle, 25 degree cutting angle, 15 degree clearance angle. 10,000 fpm cutting velocity, 0.125 inch depth of cut and 138 fpm feed. A, chip begins to form on cutting edge somewhat behind the lowest point reached by the knife. B, at the completion of the "knife mark" the chip has not yet started to split ahead of the cutting edge. Photographs C and D were taken in two stages of "roughing-off" material. Notice splitting ahead of the cutter.

or low velocity cutting and light cuts. Since many machining defects result from heavy cuts per knife because of high feed rates, a study was planned to analyze by photographic observations the actual chip-forming phenomena which take place at cutterhead velocities, rates of feed and depths of cut that are used in production plants. To conduct a study of this nature requires that high velocity motion be arrested and recorded either photographically or by some other means so that the chip formation can be observed at various stages during a single cut by the cutting tool.

The equipment to do such an investigation was assembled through the assistance of a number of individuals of several departments of the University. Since all the components must be closely synchronized to obtain the desired results, considerable attention was given to the development and installation of photographic, lighting and synchronizing equipment, to be used in conjunction with the cutting tools.

A vertical spindle shaper, equipped with a standard safety cutterhead of the inserted knife type, is used. In order to avoid the problem of setting up more than one knife to the precision required for such an investigation, one knife cutting on a 4-inch cutting circle is used.

The simple shaper offers several advantages for this kind of investigation due to ease of changing the form and material of the cutters, and ease of varying the cutting velocity over a wide range and ease of photographing the cutting action.

The stock is fed against a parallel-plane guide fence which produces a uniform cut and which may be set for the desired depths of cut. The feeding device is a friction drive wheel which slides the stock over the shaper table. Feed rates from 10 to 240 feet per minute may be selected.

Various Velocities Tested

A wide range of cutting velocities (4000 to 30,000 feet per minute) is obtained by using pulleys of various diameters on the shaper drive motor and by supplying power from a variable frequency converter.

The camera used is a Standard Speed Graphic fitted with a 4.5 lens. The axis of focus is aligned approximately with the axis of the spindle with the camera about 2 feet above the cutterhead. The photographs presented in this paper of the chips being formed were taken at f/4.5 with Kodak Super XX film. Since the photographs are taken in a darkened room, the shutter time is not critical. For convenience of operation the shutter is set on "bulb". It is tripped by a solenoid circuit which is closed by the operator's button switch at the desired time.

A light flash of short duration and high intensity duration constructed by staff members of the Chemical Engineering Department of the University was the key device in this research project. The light source was adjusted for this investigation to produce a single flash of 8 microseconds duration which is synchronized with the rotation of the cutterhead. A mechanical contactor attached to the shaper spindle acts as a switch in series with an electronic tripping switch. The contactor activates the light only when the electronic tripping circuit is closed by the operator. The tripping circuit automatically opens after a single flash from the light and will not close again for a second or more, even though the operator should continue to press the switch button. This time

lag permits the operator to release the switch before a second flash occurs.

Dynamometers are now being constructed so that cutting forces may be measured during the various phases of chip formation in order to obtain additional data on knife cutting.

Hard maple specimens 36 by 8¾ inches conditioned to 6–8 percent moisture content were used in this preliminary study. The cuts are made on the ¾ inch dimension of the stock. The photographs, Figure 3, were taken at the cutter velocity of 10,000 feet per minute, 0.125 inch depth of cut at 138 feet per minute feed.

Two Critical Stages

It appears that there are two critical stages in chip formation, the first of which is shown in Figure 3, A and B. When the knife contacts the workpiece the cutting edge should be oriented that the cutting forces are most favorable for the separation of the chip from the surface being formed. If the knife is at an angle so that the chip forms and moves along the face of the tool, as shown in Figure 1, the resulting surface will be good. From this condition which produced the best surfaces, the cutting angles can be varied to produce surfaces such as those shown in Fig. 4 at −10 degree and zero degree cutting angles. At those cutting angles, the chips do not buckle and slide up the face of the blade but are compressed and splitting occurs ahead of the cutting edge. The edge of the blade then scrapes along the surface and, because it generally lacks the keenness required for smooth scraper action, bends and tears the wood elements, leaving the torn fibers.

Referring again to Figure 3, the second phase of chip formation can be seen in photographs C and D. In photo C, the chip is splitting off the surface ahead of the knife and the cutting edge is not in contact with the surface. At this stage of the chip formation, the cutting edge has no influence on the surface quality. From the standpoint of efficiency of chip removal, the chips shown in photographs C and D are preferred because less energy is consumed than when the chip is broken up and forced along the face of the knife. The ideal in cutting, therefore, is to produce chips at the early stages of the cut such as are shown in Figure 3 A and B. Then for efficient removal of excess material the chips as shown in C and D are desirable provided that the grain direction is such that it runs out of the surface in respect to the cutterhead rotation, as in Figure 2A. The type of chip formed has little influence on the surface produced after position 3B.

Figure 4.—Effects of variation of cutting angle on surface quality when shaping aspen. Side grain (against the grain) cutting −10 degrees, torn grain; 0 degrees, torn grain; 10 degrees, no defect; 20 degrees, slight fuzzy; 30 degrees, fuzzy grain. Arrow at bottom of photo indicates direction of cut.

It is simple to understand also, after observing the chip formation in Figure 3-D, how a torn-grain surface as shown in Figure 2-B results when the fibers of the wood lead into the workpiece. In production the torn grain may be eliminated or at least reduced in severity by increasing the cutterhead velocity and/or the number of knives, or, machining at a lower rate of feed. By this procedure, the chip thickness will be reduced and the splitting will not occur far enough in advance of the cutting edge to produce torn grain.

At about this point, the question is usually raised concerning the reversing of the cutterhead rotation in respect to the feed, i.e. "up-cutting" vs. "down-cutting," as in Figure 5. The major advantages of down-cutting are: 1) the chips are not split ahead of the cutting edge, which eliminates or largely reduces the factors that encourage torn grain. 2) The cutting edge is in contact with the work for a shorter distance thus increasing tool life. 3) Because down-cutting tends to draw the workpiece through the machine, less power is required to operate the feed mechanism. 4) For the same number of knife cuts per inch, down-cutting permits a higher production rate. 5) The principal cutting forces tend to hold the workpiece against the reference surface of the machine thereby reducing vibration and flutter of the work.

Machines operating on the down cutting principal cannot be hand-fed because the tendency of the workpiece to be drawn into the cutterhead could result in accidents and injury to personnel and the machine itself. The feed mechanism must be back-lash free and the stock firmly clamped. Further, more power would be required to make a cut because the knife would be cutting across-the-grain and not splitting the chip as previously discussed. It is the opinion of the author that down-cutting may be an efficient way to remove material on some machines but it will not replace up-cutting on the more simple, non-rigid machinery, especially those that are hand fed. The advantages of one method over the other cannot be resolved by conjecture alone, the problems must receive intensive study and thorough investigation.

Tool Design and Maintenance

Since knife marks per inch is the measure that is most frequently used in judging surface quality in cutterhead type of machining, a brief discussion of the subjects is in order. A planer with 6-inch diameter four-knife head revolving at 3600 rpm produces 30 knife marks per inch when the feed rate is 40 feet per minute. Because the cutting is done while the stock is advancing at a uniform rate, the knives describe cycloidal rather than cylindrical paths through the workpiece, the characteristics of which are determined by the velocity and diameter of the cutterhead, number of knives cutting and the rate of feed. The depth of the knife marks can be found from the equation,

$$h = \frac{r}{8}\left(\frac{1}{mr \pm \frac{k}{2\pi}}\right)^2$$

where h = height of knife marks (inch)

r = radius of cutting circle (inches)

k = number of knives, use $+\frac{k}{2\pi}$ for upcutting and $-\frac{k}{2\pi}$ for downcutting

m = number of knife marks per inch computed from

$$m = \frac{\text{rpm} \times k}{\text{feed (feet per minute)} \times 12}$$

Using the above example, the height of the knife marks would be

$$h = \frac{3}{8}\left(\frac{1}{30 \times 3 + \frac{4}{2\pi}}\right)^2$$

$h = 0.000045$ inch.

Because of the small dimension of the theoretical height of knife marks it is obvious that other factors such as revolution marks due to runout of the cutter and/or the lack of precision grinding can obliterate some of the knife marks.

Inaccuracies in grinding are generally compensated for by jointing the knives. Jointing is generally done with the knives rotating at the operating speed of the machine. This procedure tends to correct the errors of knife grinding but does not correct bearing runout because jointing is done while the arbor is not under the same load as it is during the cutting operation.

Actual research has shown that a heavy joint on a set of knives requires twice as much power to remove the same amount of material as with a set of knives without jointing. A fact that is generally overlooked is that the clearance angle (angle formed by tangent to cutting circle at the cutting edge and the back bevel of the knife) actually changes as the knife advances through the workpiece. Assuming that jointing reduces the clearance angle to zero at the cutting edge, then it is true that the land produced by jointing actually compresses the wood because of the continuous feed of the workpiece during the cut. This condition is what causes what is generally termed "pounding" or "hammering". Martellotti (5) determined the minimum clearance angle for metal milling by the formula:

Minimum clearance angles =

$$\cos^{-1}\frac{R-d}{R} - \tan^{-1}\left[\frac{2\pi\sqrt{2Rd-d^2}}{2\pi(R-d)+F_tT}\right]$$

where: R = radius of cutter, inch
d = depth of cut, inch
F_t = feed per tooth, inch
T = number of teeth in cutter

Minimum clearance angle =

$$\text{Cos}^{-1}\frac{3-0.1}{3} - \tan^{-1}\left[\frac{2\pi\sqrt{2\pi\times 2.9+0.033\times 6}}{2\times 3\times 0.1-.01}\right]$$

$= 0.17°$

Besides causing "pounding", the land on the knife actually exerts a force on the workpiece counter to the direction of feed. This force is, of course, in addition to the cutting force. Jointing compresses surface fibers and makes hand feeding more fatiguing to the operator.

In much of the foregoing discussion implications have been made concerning the design of cutterheads and knives. The designer is confronted with innumerable problems which is complicated by the lack of standards in the manufacture of woodworking machinery. Not only are there large numbers of wood products manufacturers who require large varieties of knives, but in addition the knife and cutterhead manufacturers are expected to furnish cutting tools for machine and arbors that were made fifty to seventy-five years ago. Because of this situation, supplying cutterheads, saws, and bits is largely a custom business. A few years ago, the American Society of Mechanical Engineers, Wood Industries Division, through a Sub-Committee, surveyed woodworking machine manufacturers to determine the number of arbor sizes of saw 24 inches diameter and under. Quoting from a report (6) of the committee. "The useful returns represented 64 machine manufacturers reporting on a total of 280 types of saw arbors. Certain machines reported had several saw arbors, sometimes of different diameters. Others had diamond shaped or square arbors, rather than round." A situation such as this cannot possibly provide low-cost cutting tools to the wood products manufacturers. The problems that exist in having large numbers of saw arbor also plague the cutterhead manufacturers. Not only are the arbors of various diameters, but the tolerances vary so that compensating devices are needed to make the cutterheads fit the arbors. It is hoped that the present efforts toward standardization will continue at an accelerated rate.

There are many other problems that merit consideration in a report on cutting knife problems but due to time limitations they must be deferred for discussion in subsequent papers.

Acknowledgments

The research on the cutting action of knives was made possible through a generous research grant by the Kroehler Foundation, Naperville, Illinois. Mr. Harold E. Worth, formerly Wood Technologist, Department of Wood Technology, and Mr. Norman C. Franz, Research Associate, Engineering Research Institute, University of Michigan, spent many hours devising and building apparatus that was needed to make the photographs of cutters in action. Thanks are expressed also to Mr. Gerald Davenport, University of Michigan Engineering Research Institute, for his assistance in developing the photographic techniques.

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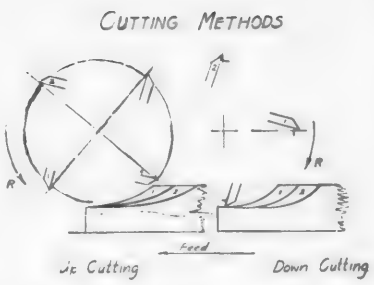

Figure 5.—Comparison of cutting action of knives in down-cutting and up-cutting. Note the difference in knife path lengths by the two methods.

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MAKING IT TOUGH

A project that whets one's imagination is underway at the TECO Lab in which efforts are being made to develop a process or material to increase the toughness of wood through impregnation. Preliminary tests have shown increases up to 30%.

Research by many laboratories had already developed impregnation materials and procedures that have increased, substantially, wood's hardness, its bending strength and its dimensional stability—but all at the sacrifice of toughness. Indications are that this current project, for a private client, will be successful in improving one of wood's natural characteristics. This will mean a better wood product, a stronger hold on its market. . . . from Research Bulletin, NLMA.

Laminating Small Timbers and Dimension Lumber From Southern Yellow Pine[1]

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Laminating of 1x4's to make 2x4 studs is described. Work is being carried out successfully on a commercial basis although operation is still in pilot plant stage. Primary purpose is to produce a better product than otherwise possible. Other items such as porch columns and crossarms are also being produced. Future developments anticipate more complete utilization of short lengths and more economical operation.

THE PRODUCTION OF GLUED laminated structural members has reached a high degree of refinement during the past ten years. Due to extensive research on the use of adhesives which permanently bond the laminates together, and because of tremendous improvement in the techniques of laminating, the lumber and wood products industry is now in a position to supply a large variety of glued laminated wood products. The purpose of this paper is to describe the production by the Southern Pine Lumber Company at Diboll, Texas, of glued laminated members which have not been heretofore produced commercially.

It should be noted that the facilities described in this paper are not presented as an ideal plant, but as a pilot plant providing the desired technical data for future production operations.

Types of Products

The primary new product manufactured at Diboll is the laminated 2 x 4 stud, 8 feet and 10 feet in length. This pine stud is made by face-gluing two 1 x 4's and is finished to standard dimensions of 1⅜" x 3⅜". It has recently been accepted by the Federal Housing Administration for use in home construction and is enjoying great popularity in Texas at the present time. Over 95% of the warping ordinarily encountered in dimension lumber is removed by this laminating procedure. Another new product at Diboll is the laminated crossarm. In cooperation with the Bell Telephone Laboratories at Murray Hill, New Jersey, a laminated arm has been developed, which will take the place of the Western Electric type DE arm. This product is produced from six 1 x 4's and is finished to 3½ x 5" x 6'. Work is proceeding on 10,000 of these laminated arms to be used in a field trial throughout the Bell System. The results of this trial will provide valuable data in designing laminated arms for each type of crossarm now purchased by Western Electric Company.

A new product which is expected to have great appeal with the home builder is the laminated 4 x 4 porch column. An order was just recently shipped to Ville Platte, Louisiana for use in a Public Housing Authority Project. Southern Pine Lumber Company is working on several other laminated products in this field.

Reasons for Laminating

The reasons for producing laminated products of this type are twofold. The first is to obtain a quality in the finished product which is not otherwise available, and this is the primary objective in producing laminated studs. The laminated studs stay straighter and may actually be stronger than solid studs of similar grade. By manufacturing laminated 4 x 4 porch columns it is possible to obtain a finish grade not otherwise available in 4 x 4's. The porch columns delivered to Ville Platte were B & Better finish and were guaranteed not to become defective due to warping.

The second reason for laminating is to obtain a better utilization of lower grade lumber. This is the basic conception behind the laminated crossarm which uses 1 x 4 No. 2 common for the inside laminates and 1 x 4 No. 1 common for the outside laminates. This method results in the best use of the allowable stress in each laminate. In porch columns, it is possible to use No. 1 and No. 2 boards selected with clear edges for the inside laminates. Thus common lumber becomes integrated in a product with B & Better finish.

The lumber used in laminating is southern yellow pine 1 x 4 and 1 x 6. 1 x 4's are used in all products thus far described. Several products using 1 x 6 are being considered. The 1 x 4 is dressed S4S to ⅞" x 3⅞", while the 1 x 6 is dressed to ⅞" x 5¾". The length is from 6 feet to 10 feet, depending on the finished product. No end joints are used.

The dressing is performed on a standard matcher, preferably during the day in which the gluing is done. However, with the glues used no difficulty is experienced in gluing up stock which has been dressed for as much as two weeks, other than the fact that the top pieces in the stack are sometimes covered with dust and therefore must be rejected. A hit or miss finish is of no consequence on the narrow faces of the stock, but pieces which are used on the inside of a product cannot have skip dressing on the wide faces. When using heavy glue spreads, as is done at Diboll, minor torn grain and other small surface imperfections are permitted on the inside laminates. The moisture content of all stock must be between 8 and 16 percent and is usually in the range of 10 to 13 percent.

The laminates must be graded according to their location in the various products. These products call for grades all the way from B & Better down through No. 2 Common. In addition to the standard grade restrictions there are certain limitations on the individual laminates in that characteristics such as medium and heavy pitch, large pitch pockets, and unsound knots which could chip out during final dressing, are not allowed. There are also some special limitations which vary with the product and the customer, one example being the limitation of the knot size in certain areas of the outside laminates of crossarms. Another forbids compression wood in 2 x 4's or in crossarms. In spite of these special restrictions it is possible to use as much as 90 percent of any standard lumber grade in the ordinary production of laminated products.

At the present time two types of glue are used. The first is an acid catalyzed phenolic compounded so as

[1] Presented at meeting of the Forest Products Research Society, Deep South Section, November 7, 1952, at Baton Rouge, La.

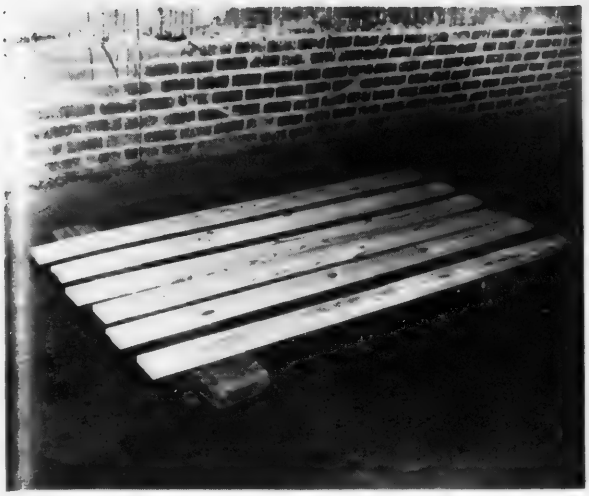

Figure 1.—Typical pine 1x4's used in making laminated cross-arms.

Figure 2.—View of laminated cross-arms ready for dressing and boring.

Figure 3.—Clamp carrier (rear end) laminating southern yellow pine 2x4's.

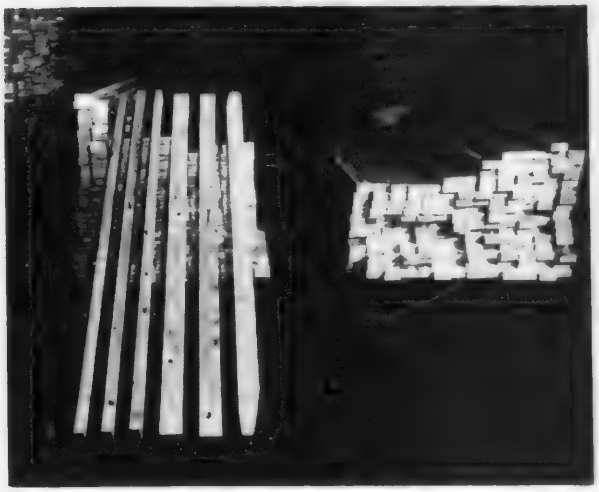

Figure 4.—Laminated 2x4's ready for dressing.

to give a pH of 2.5, or above, for the set glue film. This glue is used on interior products, most of which are subject to FHA or PHA approval. The second glue is a resorcinol-phenol combination which is used on all exterior work. However, both of these glues will pass the pressure-vacuum cyclic test in the specification MIL-A 397. The glue is single spread at the rate of 60 pounds per thousand square feet. A double spread has been requested by some customers and will be used as soon as the proper equipment can be installed. It should be noted, however, that there is no evidence from lab tests or practical experience that single spreading has caused even one faulty glue line. As long as adequate pressure is applied to the assembly, single spreading will apparently give a satisfactory product fabricated with southern yellow pine.

The glue is applied with a single roll spreader. This spreader has a water jacket which is used to keep the pot cool in the summer. Ordinary tap water is circulated through the jacket, but during hot weather this cooling system was found to be inadequate.

After the glue has been applied the work is assembled on a lay-up table consisting of a simple wood frame work with three ½ inch steel rods lying across it. The laminates are assembled on edge across these rods, and a sheet of paper is placed underneath to catch the excess glue. There is practically no open assembly time since the laminates move immediately from the spreader to closed assembly. Closed assembly time is short, usually around five minutes. Experience in Diboll indicates that there seems to be no minimum assembly time for the adhesives used, regardless of the solids content.

A clamp carrier of the 60 section by 10 foot size is used for obtaining the desired pressure of 150 psi on the assembly. This machine has what is known as thick stock clamps, which means that actually only 30 sections of clamps are available for the work. The clamps will take laminates up to 6 inches in width. All who have worked with a clamp carrier know that there is much difficulty in obtaining a uniform pressure, and this difficulty is the main objection to the clamp carrier system for laminating. In Diboll the clamp handles are turned with a ¾" air powered impact wrench. This wrench allows the clamps to be tightened much faster than by hand, and it also helps to obtain more uniform clamp pressure. The air wrench is suspended from an overhead trolley track and counterweighted so that it can be swung up above the clamps, where it is available at any time to the operator.

A brick enclosure has been constructed around the clamp carrier and a temperature of approximately 115 to 120 degrees F. is maintained in this enclosure. The work stays in the clamp a minimum of three hours, which means that the innermost glue line reaches a temperature of approximately

(Continued on page 86)

Curved Plywood, Its Production and Application in the Furniture Industry[1]

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Trend toward more functional design in consumer goods has brought about a tendency to use other products such as plastics and metals for many products formerly manufactured exclusively of wood. Article reviews various accepted methods available for production of curved plywood and describes a new process developed by the Canadian Forest Products Laboratory. Continued research is necessary to help wood maintain its competitive position in the area of consumer goods.

SINCE THE END of World War II, there has been a growing trend toward more functional designs in consumer goods, including furniture. Modern designs generally have more simple lines with pleasing, graceful curves. Products are lighter—yet often stronger—and thus make more efficient use of materials.

Coupled with this functional trend in the furniture industry, there has been a tendency to use new materials, such as plastics and light metal alloys, for many products formerly manufactured solely from wood. Products made from these new materials are not necessarily superior to the wooden article; furthermore they usually lack the charm and aesthetic appeal of natural wood. Why then are these materials making such inroads in the wood products field? One reason is that these materials lend themselves more readily to mass production of products designed to emphasize curves rather than massive rectangular motifs.

If the furniture and woodworking industries are to regain or at least retain many of their markets it appears that they must look to methods for producing curved wooden shapes quickly and efficiently. Fortunately the march of science which fostered plastics and light metal alloys also provided some new tools and techniques for the production of curved plywood and curved laminated veneers which can form the basis of many modern furniture designs.

Various established techniques, available to the furniture industry, for the production of curved plywood are reviewed in this paper. The applications for which the different methods are best suited are discussed, and a process, developed at the Ottawa Laboratory of the Forest Products Laboratories of Canada, for the production of curved plywood is described.

In this paper the term "curved plywood" is defined as plywood permanently shaped in simple curvature, that is, curved in only one plane as opposed to plywood curved in compound or double curvature as, for example, the surface of a sphere. Plywood shaped in double curvature finds very little application in the furniture industry and is not considered in this paper.

While there are many different production techniques, there are only two basic methods of producing curved plywood. Permanent bends can be made in normal plywood previously glued in a flat condition or veneers can be bent and glued to a curved shape. Curved plywood produced by the former method is sometimes called bent plywood.

Bending of Flat Plywood

One of the oldest and simplest methods of bending lumber-core plywood of 5-ply construction is to make a series of equally spaced saw cuts into the back side of the panel through the lumber core to, and in some cases, slightly into the cross-bands. Removal of wood by these cuts allows the panel to be bent. The total width of all saw cuts should slightly exceed the difference between the lengths around the inside and outside arcs of the curve. Special attention must be given to the spacing and depth of the saw cuts to avoid ridges showing in the curved face. Sharp saws should be used to prevent pieces of wood in the core from breaking out. The grain of the face veneer should be at right angles to the axis of curvature and in some cases it may be necessary to dampen or steam the outside surface of the face veneer to reduce hazards of wood rupture. The panel is of course greatly weakened by the saw cuts and in order to strengthen and stabilize the curve, the inner portion must be reinforced by gluing in a curved block insert or a strip of veneer. (see Figure 1).

In cases where a smoother curve and a sturdier construction are required, the back veneer, the back cross-band, and the core may be removed completely from the area of curvature with a special cutter. A smooth curve, either concave or convex can then be made in the face and cross-band veneer. Curved plywood made by this method must be reinforced with solid wood, accurately shaped to fit in the space formed after bending where the material was removed from the back.

New Method

An interesting new method of producing curves in thick plywood was developed recently by the Forest Products Laboratory in Great Britain. In this method all the material in the area of curvature is removed from the back of the plywood leaving only the face ply. A piece of low density wood, such as balsa, is glued in the recess—with its grain parallel to the axis of curvature. The face ply is moistened and the plywood is bent around a heated jig. It is claimed that smooth curves of very short radii can be produced by this method.

The saw cut technique can be used for bending thick 3 ply constructions except that in this case the cuts to remove wood extend almost through the core. Again the curve formed is reinforced by gluing a strip of veneer to the inner portion of the curve. (see Figure 2). This bending operation is best accomplished in a special bending machine designed for the purpose which makes the bend and at the same time applies heat and pressure to the reinforcing veneer until the glue is cured.

Another technique used for bending thin, flat plywood (¼" thick or less) is based on the fact that wood becomes more plastic when heated and can then be bent to more or less permanent curves. Special plywood bending machines have been developed for

[1] Presented at meeting of the Forest Products Research Society, Eastern Canadian Section, March 5–6, 1953, at Toronto, Ont.

this process. In one such machine the plywood is rocked back and forth between three steel rollers—one of which is heated—until the desired degree of curvature is reached. Steaming of the plywood facilitates bending to shorter radii. This type of bending machine produces continuous curves which have some tendency to open on cooling and therefore, is generally used for making plywood drums rather than for producing curved plywood shapes for furniture.

A plywood bending machine of another type is designed to produce bends of short radii. The plywood is pressed between a concave die and a heated cylinder. An advantage claimed for this method is that curvature can be stabilized by gluing a small piece of veneer or thin plywood on the concave side of the curve with a thermo-setting resin adhesive. The bending and gluing are done simultaneously. Heated cylinders of diameters from two to ten inches are available and the concave die can be adjusted to accommodate cylinders of different diameters and a range of plywood thicknesses. Thick plywood can be bent in this machine by first removing the back of the plywood by saw cuts as already described.

In the methods described thus far plywood is bent from the flat condition in which it was originally glued to a curved shape. It will be appreciated that after bending, the plywood is in a stressed condition. For many furniture applications where the curved plywood fulfils a decorative function only as in waterfalls, radio and television cabinets, and is braced by a sturdy framework, bent plywood gives very satisfactory service. However, in many modern functional furniture designs the curved plywood must possess certain strength qualities, in addition to decorative attributes, and must be capable of retaining its shape without support and resisting stresses which tend to make it straighten out. Some examples of this type are curved table and chair legs, chair seats and backs, church pews, and arm rests. For requirements of this nature curved plywood made by bending flat plywood is seldom satisfactory and the curved plywood should be made by forming the veneers during the gluing operation. This type of curved plywood is here referred to as bonded curved plywood.

Methods of Bonding Curved Plywood

There are two basic requirements for the production of bonded curved plywood in quantity:

(a) A pressure system for bending veneers to the desired shape and for applying normal gluing pressure until the glue is cured.

The pressure systems available include fluid pressure (bag moulding) die or form pressure, flexible band pressure, and various combinations of two or more of these methods.

(b) A heating system to accelerate curing of thermo-setting resin glues. The principal heating systems available include steam, hot water, strip heating, and dielectric heating.

The different pressure systems are first described, and the various heating methods applicable to each type of pressure system are then discussed.

Fluid Pressure

The furniture industry was among the first to use fluid pressure in the form of the vacuum bag for bonding curved plywood. Briefly the procedure consists of laying the veneers, which have previously been spread with glue, on a male form and then placing the form and veneers inside a flexible bag or under a blanket of impermeable material such as rubber. A vacuum is drawn inside the bag or blanket which causes atmospheric pressure to force the veneers to take the shape of the form. The vacuum is maintained until the glue is cured. (see Figure 3.) This technique has been widely used and is still in use in some plants although it has a number of disadvantages. The maximum pressure which can be applied is limited to less than 15 lbs. per square inch and the rate of cure of the glue—and hence the rate of production—is extremely slow. However, the process can be modified to overcome these objections. Instead of exposing the bag or blanket to atmospheric pressure the entire assembly can be enclosed in a pressure chamber or autoclave capable of withstanding considerable pressure of air and/or steam. (see Figure 4). A vacuum may be drawn on the bag or the bag may be merely vented through the autoclave to normal atmosphere. Compressed air or steam or a combination of both is introduced into the autoclave which drives air out of the bag and forces the bag and veneers tightly against the form. In this manner pressures up to 100 lbs. p.s.i. can be ap-

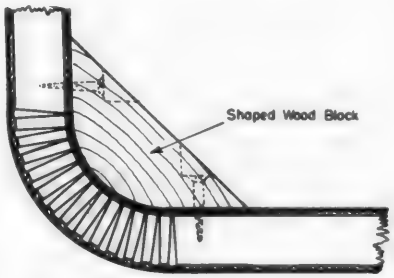

Figure 1. Lumber-core plywood bent by saw-cut method. Curve is reinforced with shaped wood block.

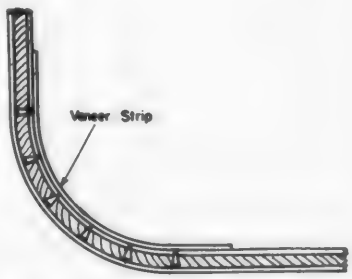

Figure 2. Thick all-veneer plywood bent by saw-cut method. Curve reinforced with strip of veneer.

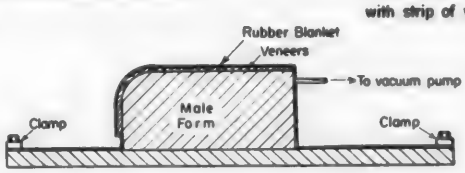

Figure 3. Bonding curved plywood by vacuum-bag method.

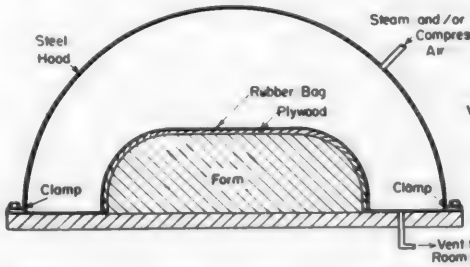

Figure 4. Bonding curved plywood by vacuum-pressure method.

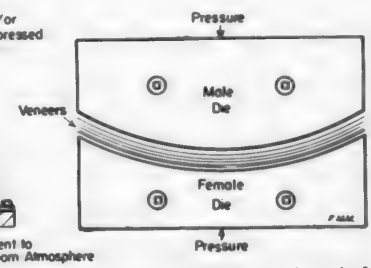

Figure 5. Bonding curved plywood of moderate curvature by means of solid male and female dies.

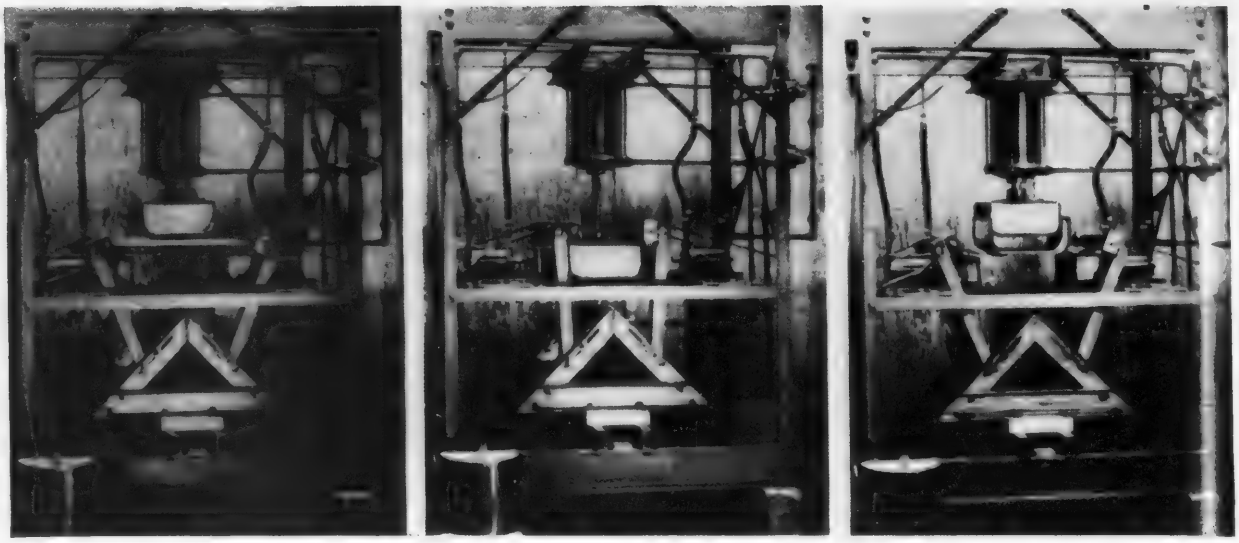

Figure 6.—Press for bonding curved plywood—developed at Forest Products Laboratory, Ottawa, Ont. Left: Veneer with glue applied is placed on pressure band in open press. Center: After veneers are bent to shape, glue is cured by dielectric heating. Right: Cured plywood section ready to be removed and trimmed. Total cycle: 85 seconds.

plied. Furthermore, by using steam as the pressure medium, the heat accelerates curing of the glue. Special machines are available for this process. The veneers are placed on the form which is mounted on the table of the machine and a sheet of rubber is placed over the veneers and form. Then a strong, semi-cylindrical hood is lowered and securely clamped to the edges of the table making an air-tight seal between the hood, the rubber and the table top. Steam and compressed air are introduced between the hood and the rubber blanket applying both heat and pressure to the veneers.

There are several variations of the vacuum pressure system but the basic principle of fluid pressure is essentially the same in all. Although used extensively during the war for aircraft and to some extent since the war for boats, the vacuum pressure method of bonding curved plywood has not gained wide acceptance in the furniture industry in Canada. This is because production is slow and operating costs are comparatively high.

Die Pressure Systems

For bonding curved plywood of slight or moderate curvature such as chair backs and drawer fronts the simplest method of applying pressure is by means of a pair of solid dies or forms (see Figure 5). The forms, which can be made from laminated wood at low cost, are placed in a screw or hydraulic press and pressure is applied and maintained until the glue has cured. In order to obtain increased production from the press a series of nesting forms can be used and placed one above the other in the press. To compensate for slight imperfections in the shaping of the dies their faces an be lined with sheet rubber.

In cases where the shape desired is such that the pressure applied at some locations may be inadequate the forms can be lined with foamed rubber which approximates the effects of fluid pressure. A special type of curved plywood, well known to the furniture industry, is lumber-core plywood made with band sawn lumber cores. This plywood is either bonded in a die-pressure system or the assemblies are stacked and a number pressed at one time.

Heating Methods for Die Pressure Systems

In order to make efficient use of the dies and press, and to obtain maximum production, it is advantageous to provide some means of applying heat to the dies. In this way it is possible to accelerate curing of thermo-setting glues used for bonding. If a very large production is required of one item, metal dies—either cast or fabricated from steel plate—which can be heated by steam or hot water may be justified. Surprising results can be achieved in this respect with a little ingenuity. A few years ago in a small plant in the United States, I saw a pair of hot-water heated dies made by simply imbedding copper tubing in ordinary bearing metal.

However, in Canada, the quantity required of any one curved shape is seldom great enough to warrant the cost of metal dies. Consequently strip heating, dielectric heating, or some other type of heating, is usually more satisfactory.

Strip Heating

Strip heating is the term applied to the heating of sheets of metal by passing through them a high amperage current from a low voltage transformer. When sheets of metal are fastened to the face of the dies they provide heat for curing the glue. One important advantage of strip heating is that the equipment required is comparatively inexpensive. Unfortunately, the shape of the metal sheet which it is practical to heat by strip heating is rather limited. The term strip heating is very appropriate because this method of heating operates best when heating narrow long strips and becomes progressively less satisfactory as the sheet metal approaches a square shape. Therefore, while strip heating is an excellent method of applying heat for gluing bands to the edges of panels, it does not lend itself to bonding the curved plywood shapes used in furniture.

Another method of electrical heating, used successfully with solid dies, is to imbed electrical heating wires in a resin-impregnated fibreglass sheet—shaped to fit the faces of the dies. The advantage of this method is that ordinary 110-volt power is used and no low-voltage transformer is necessary. From time to time reference has been made to the use of an electrical conductive rubber blanket for use with solid dies but I have no information on the results obtained by this method of heating.

Dielectric Heating

From a technical viewpoint dielectric heating appears to be the most satisfactory method of applying heat to die pressure systems. It provides

very rapid heating to all glue lines regardless of their position in the assembly. Because heating is uniform, distribution of moisture in the veneers is not greatly disturbed and this reduces to a minimum any tendency of the curved section to warp in service. The dies can be made at low cost and lined with sheet metal which serves as electrodes. The main disadvantages of dielectric heating are the initial cost of the equipment and the unfamiliarity of the furniture industry with its use.

Pressure Band System

The shape of curved plywood which is most versatile—so far as the furniture industry is concerned—is the U shape. This shape and simple variations of it can form the basis for a wide variety of furniture components, such as chair and table legs, school furniture, chair backs and back supports, arm rests, radio and television cabinets. Unfortunately it is surprisingly difficult to successfully bend and bond veneers to a U shape. Repeated attempts by many manufacturers to bond U shapes by means of solid and semi-solid pressure dies have met with only limited success. These shapes can be produced by vacuum pressure bag moulding but, as already mentioned, this process is slow and expensive.

The problem of bonding U-shaped curved plywood has received considerable attention and study at the Forest Products Laboratory at Ottawa. The aim was to develop a simple, yet rapid method of production to compete with mass production techniques used for plastics and metals. The first problem studied was the development of a suitable pressure system. Tests made with different types of male and female dies produced no promising results. The veneers tended to tear along the sides of the U as the male form was pushed inside the female form. It was found that the tearing difficulty could be overcome by splitting the male form so that it could be contracted during insertion and then expanded when in place; however, there was still a problem of breaking and wrinkling of the veneers at the corners.

It was decided to experiment with a pressure band to form the veneers around a male form. This procedure appeared to offer several advantages. The problem of tearing the outer veneer would be eliminated as there would be no sliding friction to cause tensile stress. The pressure band would support the outer veneer and apply pressure around the outside radius of curvature during bending. It would thus be possible to obtain smaller radii of curvature without danger of rupture.

A number of tests were made with a U-shaped male form and a pressure band. As a result it appeared that the ideal technique consisted of applying pressure first on the flat bottom of the U, then at the corners by means of a pressure band, and finally along the sides. This sequence of pressure applications caused the veneers to bend with a minimum of wrinkling and breaking. It was then necessary to design a machine incorporating these principles which in addition could be quickly loaded or unloaded and could be modified by simple adjustments to produce curved plywood of different shapes and sizes.

Working Model

A working model of the press designed is shown in Figure 6. Four, double-acting, pneumatic cylinders are employed to supply the necessary bonding pressures. The stainless steel pressure band is supported by four vertical spring-loaded arms, pivoted at the bottom and free to swing in at the top. The glued veneers are placed on the pressure band as shown in Figure 6 (a). By means of one control valve, air is then admitted simultaneously to the top and bottom cylinders. Thus the two rams move toward each other supplying the necessary pressure over the horizontal section. Since the top cylinder is of larger diameter than the bottom one, the lower ram is forced down. The same action pulls in the arms supporting the pressure band, thus forcing the veneers around the form. The side pressures are then applied and the assembly is bonded. The procedure is reversed to complete the cycle. The action takes place very quickly requiring only one or two seconds to either open or close; thus loading and unloading time are reduced to a minimum.

The obvious heating method to use with this curved plywood press was dielectric heating, since it would provide very rapid curing of the glue and thus take advantage of the short open-

Figure 7.—Curved plywood sections bonded in press shown in Figure 6.

ing and closing time. The pressure band could serve as the grounded electrode and the high voltage electrode could be placed on the male form and thus be effectively insulated by the wood of that form.

The bonding cycle for an application of this kind must be based primarily on the type of glue used, the mass of wood to be heated, and the output of the dielectric heating unit. Low-temperature-setting synthetic resin glues are best suited for bonding operations of this type. Taking the curved sections shown in Figure 7 as a typical example, five, 1/20 inch birch veneers (23 by 11 inches) were heated to 220° F. with 2 kilowatts of radio frequency power in 55 seconds. The glue used cured in 30 seconds at this temperature, thus making a total bonding time of 85 seconds.

Curved plywood and laminated veneer sections made by this method have excellent dimensional stability, with practically no tendency for the curves to open up or warp.

The U form shown on the press and the semi-circular form in the same picture are but two of the numerous shapes that can be employed. In the manufacture of modern furniture, plywood bonded on forms of these two shapes alone are suitable for practically unlimited applications. Drawer fronts and bottoms, waterfalls, radio cabinets, chair legs, table legs and tops, and stands for small tables, suggest only a few of the many possible uses. Some of these items are shown in Figure 7.

General Requirements for Bonded Curved Plywood

Veneer: If only a moderate degree of curvature is required almost any combination of veneer thicknesses suitable for flat plywood can be used. Any given thickness of veneer will of course bend more readily when the direction of the grain is parallel to the axis of curvature and hence thicker veneers can be used when it is possible to orient the veneers accordingly. In cases where very sharp curves are necessary veneers 1/20 inch thick and less must be used. The higher the moisture content of the veneer the more readily it can be bent without breaking. Gluing and other requirements, however, usually impose a practical maximum of about 10 percent moisture content.

Glues: Cold-setting urea resin glues are from many points of view the most suitable for bonding curved plywood for furniture and other interior uses. They cure at room temperature when cold pressing is used, and can be cured very rapidly when heated. They do not introduce a large amount of water into the plywood. They are light in color and have excellent dielectric properties. In cases where a more durable and waterproof glue bond is required melamine-urea glues or melamine glues are recommended.

Pressure: Bonding curved plywood requires pressure to bend the veneers to the desired shape in addition to the necessary gluing pressure. A weakness of many industrial processes for bonding curved plywood is lack of adequate pressure. It is true that when using the simple vacuum bag method satisfactory results can be obtained with pressures of 14 lbs. per sq. inch but for curved sections which will be stressed in service pressures of the order of 100 lbs. per sq. in. or more should be used to ensure satisfactory results.

Conclusions

Only some high lights of the production of curved plywood and its application in the furniture industry have been touched on. It is a broad subject; and one that is receiving continuing attention. Sufficient has been said, however, to indicate the availability to furniture manufacturers of a variety of methods for producing curved plywood. It will have been noted that new techniques have been developed through research, and further studies and investigations, aimed at improving techniques and methods, are continuing.

Curved plywood produced by the appropriate method enables the furniture manufacturer to design and fabricate products of modern functional design, possessing style, grace, and sales appeal.

When selecting a method of producing curved plywood the main factors to be considered are:

(a) purpose for which the curved plywood will be used.
(b) shape of curved plywood to be produced.
(c) quantity required.

Bending of flat plywood is a satisfactory method of producing simple curved sections for decorative and unstressed applications.

Curved sections of plywood and laminated veneers which will be stressed in service, and which require good dimensional stability, should be made by bonding. Moderate curves can be readily produced using solid dies and some form of heating. More extreme curves such as U shapes require a more elaborate process such as the vacuum pressure system or the process developed at the Forest Products Laboratory, Ottawa.

RESEARCH CAN SAVE THIS MARKET

Research Bulletin, February, 1953, issue, published by the National Lumber Manufacturers Association, points the finger at furniture drawers as another market that is in danger of being lost to a competitive product—this time plastics. Plastic manufacturers are now marketing a drawer which they claim is "non-stickable." Past experience indicates this benefit will be exploited to the utmost in promoting the sale and use of plastic drawers.

Research Bulletin points out that the lumber industry could have made this claim five years ago based on wood research developments at that time. But only one manufacturer is known to have made use of this important information to give his customers a better drawer—and incidentally help close the door to competing products such as plastics.

Information on how to build "non-stickable" wood drawers is still available, and can be obtained from Timber Engineering Co., 1319 18th St. N. W., Washington 6, D. C.

The above story as told by Research Bulletin only emphasizes the need for lumber industry management to integrate research, product development and sales promotion.

Mechanisms Affecting Tangential vs. Radial Shrinkage[1,2,3]

RICHARD E. PENTONEY

Research Fellow, Department of Wood Technology, State University of New York, College of Forestry, Syracuse 10, New York

Explanation of differential transverse shrinkage is related to the location of cells, to the features of the cell wall structure, and to the distribution of the middle lamella. Using Douglas fir samples, it was found that Morath's summerwood–springwood theory largely explains the observed differential shrinkage of the gross wood.

Introduction

ONE OF THE MORE troublesome problems affecting the efficient utilization of wood is the dimensional change of the product when exposed to an atmosphere of varying relative humidity. The problem is further aggravated by the inequality of shrinkage in the three principal directions with respect to the grain: namely, longitudinally (along the grain), radially (direction from the bark to the pith), and tangentially (direction tangent of the growth rings), for a given decrease in moisture content. Along the grain, the shrinkage in normal wood is generally quite small, amounting to approximately 0.1% to 0.2% of the green dimension when oven dried. This small change is often neglected in the manufacture and subsequent use of the wood product. However, tangential and radial shrinkages are of major importance. Tangentially, wood shrinks from 4% to 14% of the green dimension when dried from the green to the oven-dry condition; while in the radial direction the corresponding shrinkage is roughly one half the tangential shrinkage for a given wood specimen. This differential of radial-tangential shrinkage is one of the prime factors causing shape distortion during seasoning of lumber and during ultimate use. It reduces the quality of precision and semi-precision wood fittings such as in furniture joints, etc. In fact, whenever wood is used in a capacity where consistency of shape is desirable, a means of differential shrinkage control would be desirable.

Probably the most widely used method of reducing the effect of differential shrinkage involves the drying of wood to a moisture content approximating the expected moisture content in service. This means is satisfactory if the service moisture conditions are known and are fairly constant, but is of little avail under other circumstances. In certain instances the method of manufacture is used as a control, especially in the case of plywood where alternate laminae are bonded so that their respective grain directions are perpendicular. Under these conditions the panel shrinks in approximately equal amounts, percentagewise, in width and length. The most direct controls of differential shrinkage and wood shrinkage are those which reduce its hygroscopicity, i.e., its ability to take up moisture (26). Several methods attempting this direct control have been presented and appear to have enjoyed some success.

It is the purpose of this report to present the principal causative mechanisms that have been proposed to explain why wood shrinks as is commonly observed. Although, longitudinal shrinkage theories are described, the more controversial radial and tangential shrinkage mechanisms have attracted the most research, particularly in regard to the difference between them, and will occupy most of our attention here. It is hoped that the presentation of these shrinkage mechanisms will aid in the understanding of shrinkage control methods.

Fringe Micellar Theory and Water Sorption

Theories concerned with differential shrinkage of wood were not generally developed until the principal features of cell wall constitution were reasonably well understood. The historical development of knowledge of the structure of cellulose, and its function in the cell wall, have been adequately reviewed (15, 16, 20, 22, 29), and for the purposes of this study it will suffice to consider a brief outline of the generally accepted "fringe micellar theory."

The theory was conceived after it had been established that cell wall cellulose is a high polymer of D anhydroglucose distributed in an approximately parallel network of long linear macromolecules having certain areas of preferred orientation (crystallites). The essential premise of the theory is that any one cellulose macromolecule may be included in several crystallites. Likewise each crystallite may contain portions of a number of parallel molecules. This arrangement results in an irregular lattice-like configuration consisting of crystallites loosely connected with each other by the intercrystalline portions of some of the cellulose molecules (Figure 1).

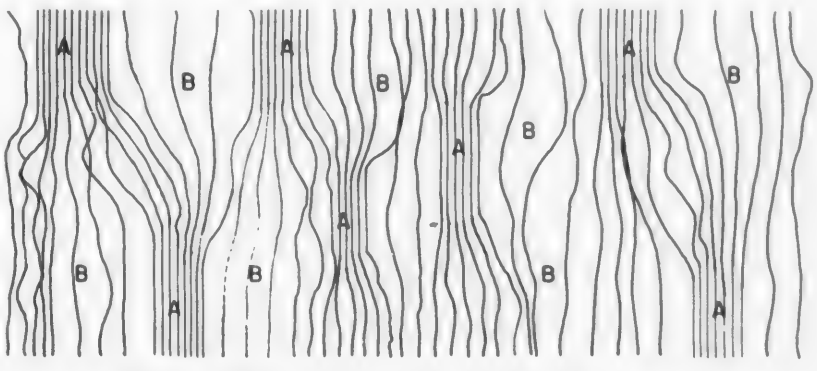

Figure 1. - Schematic diagram of cellulose lattice showing: A - crystallites; B - intercrystalline areas. After the "fringe micellar theory."

[1] Abstract of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at the State University of New York, College of Forestry.

[2] Shrinking and swelling of wood are inverse relationships. To avoid repetition this paper will deal primarily with the shrinkage aspect of the relationship.

[3] Contributed to the Journal of the Forest Products Research Society.

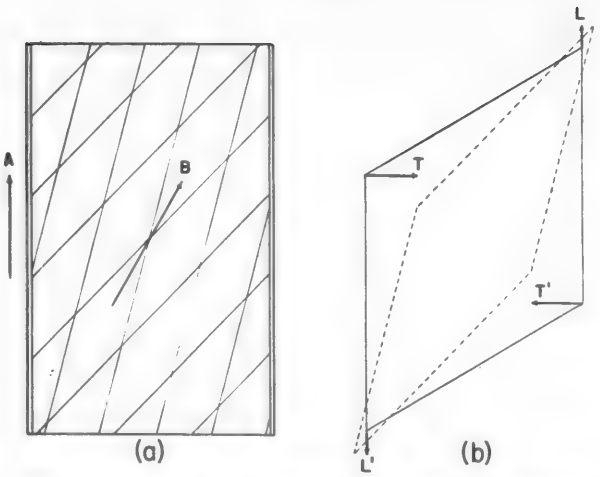

Figure 2.—Shrinkage of idealized cellulose lattice. (a) Simplified lattice structure (greatly exaggerated) in cell wall. Cell long axis and lattice axis represented by vectors A and B. (b) Vector diagram of single lattice frame. Major transverse components T and T', longitudinal components L and L'.

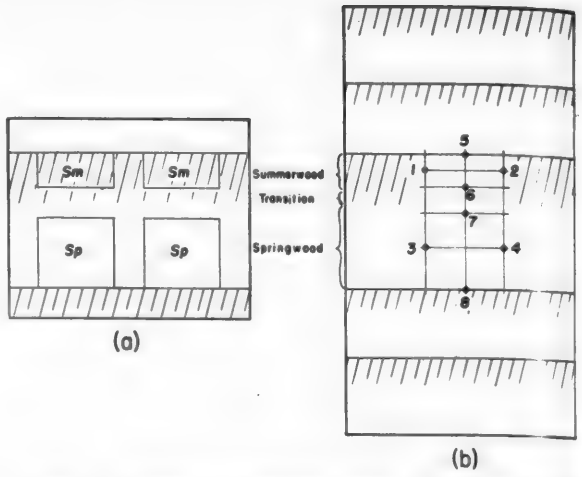

Figure 4.—Diagram of shrinkage samples. (a) Portion of test ring from which isolated summerwood (Sm) and springwood (Sp) samples were taken. (b) Gross samples showing relative ring widths and proportion of summerwood. Tangential summerwood and springwood measurements were made from 1 and 2 and 3 and 4 respectively. Corresponding radial measurements from 5 and 6 and 7 and 8. Gross radial was made from 5 to 8.

The hydrophillic nature of the cell wall is attributed to exposed hydroxyl groups occurring along the cellulose chains and on the crystallite surfaces. Water penetrating the system tends to saturate the secondary valences of these hydroxyl groups but apparently does not enter the crystallites to any measurable degree (29). The sorbed water acts as a wedge separating the noncrystalline chains and the crystallites, thus expanding the lattice. Conversely the lattice contracts during desorption of water.

Longitudinal versus Transverse Shrinkage

Cockrell (5) used a simplified symmetrical lattice concept to explain longitudinal shrinkage with moisture loss of ponderosa pine wood as shown in Figure 2.

It is well known that the lattice axis in the normal secondary wall (of which the bulk of the cell wall is composed) of longitudinal prosenchyma cells forms a helix about the long axis of the cell, at an angle of less than 45°. Reference to Figure 2 shows that observed cell dimensional changes would depend upon the longitudinal and transverse components of the lattice changes. These in turn depend upon the lattice angle (fibril angle), the length of the intercrystalline molecular chains, and the moisture content change. Thus a small component of longitudinal shrinkage results from the loss of a given quantity of water. Conversely the concomitant transverse component of shrinkage is relatively large. Although the picture is over simplified, it offers a qualitative explanation of differential shrinkage for the gross wood.

Differential Transverse Shrinkage Theories

The problem of differential transverse shrinkage is more complex than that of longitudinal versus transverse shrinkage because of the numerous factors potentially involved. The several hypotheses that have been developed to explain the radial versus tangential differential shrinkage behavior of wood may be arbitrarily divided into those which depend upon: 1) The gross structure (arrangement of cells and cell types): 2) Modifications of the average fibril alignment: and 3) Cell wall layering (primary and secondary wall structure together with the intercellular substance). It should be initially noted that some hypotheses could be classified under more than one heading. However, for simplicity the grouping was made according to the principle causative factor proposed.

Gross Structure

It was long believed that the existence in wood of radial elements (rays) restricted the shrinkage in this direction (4, 17, 25), the assumption being that the ray cells shrink little, if any, along the long axis of the cell in a manner commonly observed in longitudinal cells. Because the long axes of the majority of ray cells lie in the radial direction, it was thought that radial shrinkage of longitudinal tissue was restrained by the small ray shrinkage. Tangentially, however, the longitudinal cells could swell free of ray restraint.

Kollmann (18) found this concept to be inconsistent with the expected compressive strength of rays. The ray-restraint theory was also rejected by Ritter (23) when his polarized light experiments on basswood rays indicated a secondary wall crystalline orientation at nearly right angles to the previously assumed orientation. This evidence was supported by shrinkage measurements of isolated basswood rays which compared closely with shrinkage data from wood blocks. Barkas (2) challenged the conclusions of Ritter on the basis that the optical determination of fibril alignment was due to a preponderance of thickness while shrinkage is due to a preponderance of strength. In support of his contention, Barkas cited the influence of the primary wall in the familiar phenomenon of "ballooning."

In an attempt to further demonstrate the lack of ray restraint on the radial shrinkage of the gross wood, Ritter and Mitchell (24) measured the shrinkage of sapwood pine blocks from which the ray cells had been removed by degradative action. They conclude that the shrinkage of the rayless blocks is comparable to the shrinkage of blocks with the rays present. However, the degradation technique is not stated. There is some question as to the complete removal of rays at the center of the blocks and as to the effect of the degradation process on the shrinkage of the longitudinal tissue. Assuming the technique to be efficient, the elimination of any restraining effect the rays may have will not necessarily be evident in the shrinkage of the gross wood as may be seen by reference to Table 2 of this paper (Table 2 is discussed in later paragraphs).

Greenhill (10) has substantiated in part the contention of Ritter that the rays do shrink along the ray cell axis.

However, the former author reports shrinkage values for rays which are about one half the shrinkage values for the adjacent longitudinal cells. Apparently, the rays do not have the importance in restraining the radial shrinkage originally assumed, but it also seems reasonable that some restraining action is present. Due to the orientation and geometry of ray cells, they are operating in the direction of maximum strength (along the cell axis) regardless of the fibril orientation, while the longitudinal cells are operating in the direction of minimum strength (perpendicular to the cell axis). Perhaps the restraint is more than presently supposed. In any event, no conclusive evidence concerning the degree of ray restraint is presently available.

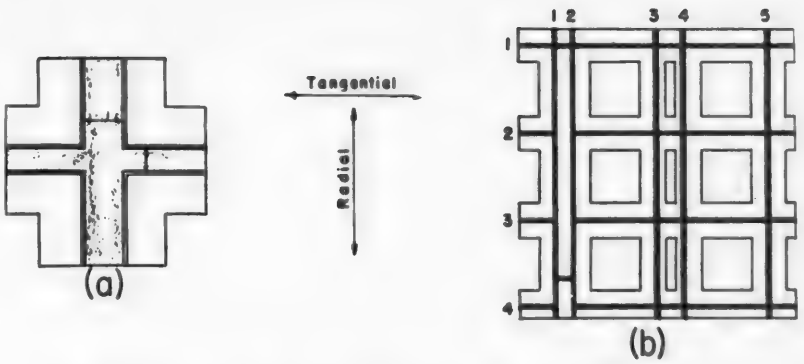

Figure 3. - Schematic cross section of coniferous wood illustrating the distribution of middle lamella substance, which, according to Frey-Wyssling, controls differential transverse shrinkage. Relatively large tangential shrinkage supposedly caused by: (a) Greater thickness of middle lamella between radial cell walls; (b) Greater number of cross walls along the tangential axis due to narrow ray cells (1 and 2 on tangential axis), and tapering tracheid ends (3 and 4 on tangential axis).

Mörath (19) suggested that the differential transverse shrinkage in temperate zone woods is caused by the alternation of summerwood and springwood increments within the annual rings. Tangentially, the net observed shrinkage is a result of the shrinkage of continuous bands of summerwood in parallel with continuous bands of springwood. Because the summerwood is considerably stronger than the springwood, which is largely a result of the greater summerwood density, Mörath believes that the springwood is forced to shrink with the summerwood in this direction. However, radially the net observed shrinkage is a result of the shrinkage of alternating bands of summerwood and springwood in series. In this direction the summerwood and springwood would be essentially free to shrink independently. In effect the theory states that the overall tangential shrinkage is the result of the tangential shrinkage of the summerwood, but radially, the overall shrinkage is the result of an average of the radial shrinkages of the summerwood and springwood. Because the denser summerwood is capable of shrinking more than the springwood, the theory predicts a greater tangential than radial shrinkage in gross wood specimens. Mörath's theory was questioned by Ritter and Mitchell (24) who found that the average of the tangential shrinkages of the isolated summerwood and springwood of longleaf pine was considerably larger than the radial shrinkage of the attached summerwood and springwood. They expect the average isolated tangential shrinkage to approximate the attached radial shrinkage if the Mörath mechanism is solely responsible for the differential shrinkage, and as their experiments did not verify this condition they conclude that the summerwood-springwood interaction is only a minor contributing factor to the greater tangential than radial shrinkage of wood.

The writer tested Mörath's theory by means of an experiment conducted on the wood of Douglas-fir, the discussion of which appears in later paragraphs.

Fibril Angle Modification

From the basic concept of the method of lattice shrinkage in the cell wall, Frey-Wyssling (7) hypothesized that deviations in fibril angle between the tangential and radial secondary cell walls account for the observed differential transverse shrinkage. He presents data which indicate that the fibril angle in the radial walls is greater than the fibril angle in the tangential walls, the difference between the two ranging between 0° and 15°, contrary in part to observations of Harada et al (11).

From Cockrell's simplified lattice it can be shown that the transverse component of shrinkage is proportional to the cosine of the fibril angle. Using this proportionality as a first approximation, the ratio of tangential shrinkage to radial shrinkage (in percent of swollen dimension), herein referred to as the T/R ratio, may be obtained from the ratio of the cosines of the corresponding fibril angles. If the tangential fibril angle is 15° and the radial angle is 30°, the calculated T/R ratio is 1.11. Since the observed T/R ratio is commonly 2 (4) it appears doubtful that the small deviations in fibril angle observed can be of major importance in differential transverse shrinkage.

Ritter and Mitchell (24) have extended the concept of fibril angle modification to include the local effects of cell wall pits. Very few pits are found in the tangential walls of coniferous tracheids but they are numerous in the radial walls. In the vicinity of intertracheid pits, the fibrils are deviated from their normal direction to a circular configuration, which would tend to produce a higher average fibril angle in the radial than in the tangential wall. Consequently, the authors expect a reduced radial shrinkage in softwoods which may be traced to the pits.

However, it can be shown (21) that even for the extreme case of a cell with a radial wall entirely composed of circular pits, the average fibril angle cannot exceed 45°. From this condition the maximum T/R ratio possible is 1.42 (obtained by assuming the fibril angle of the tangential wall to be 0°). When normal cells are considered, the pits occupy 30% to 50% of the radial wall and the theoretical T/R ratio drops to approximately 1.2. It appears that this may be a mechanism contributing to differential shrinkage but, of itself, cannot explain the observed T/R ratios.

Cell Wall Layering

Frey-Wyssling (8, 9) reversed his earlier position and presented a theory founded upon the heretofore neglected compound middle lamella (Mittelschicht). From his investigations, Frey-Wyssling concluded that the shrinkage properties of the colloidal true middle lamella, which apparently consists primarily of lignin (12), is a major cause of differential transverse shrinkage.

Frey-Wyssling believes that the secondary wall is ineffectual in anisotropic shrinkage, but is important with respect to volumetric shrinkage. He explains that although the cells, apart from the compound middle lamella, shrink considerably in the transverse plane, the tangential and radial shrinkages are nearly equal, and the differential shrinkage is caused by the middle

lamella substance surrounding the cells. The shrinkage of the cells, being greater than the shrinkage of the middle lamella, contributes a greater proportion of the volumetric shrinkage.

He accounts for differential T/R shrinkage by the relative amounts of middle lamella tissue present perpendicular to the principal wood axes, which in turn is a function of the number of crosswalls per unit length encountered along the axis and the thickness of the middle lamella in these crosswalls. Working with larch, Frey-Wyssling showed that in the transverse plane, more crosswalls per unit length were present along the tangential axis than along the radial axis (the narrow ray cells and tapering tracheid ends providing the additional walls observed in the former direction), and that the ratio of the two is highly correlated with the T/R ratio of the gross wood. He also found that the thickness of the middle lamella between radial cell walls exceeds the thickness between tangential cell walls (Figure 3).

Qualitatively, the mechanism may be correlated with much of the observed shrinkage phenomena. However, from a quantitative standpoint the actual shrinkage and volume of the middle lamella must be observed to support this hypothesis. Due to experimental difficulties this evidence is lacking. Nonetheless, the hypothesis appears to merit further investigation when the experimental difficulties are overcome.

Experimental

The experimental portion of this study was designed to determine the influence of the shrinkage of the summerwood and springwood increments within the growth ring of a typical softwood on the overall shrinkage of the gross wood. This was to test the validity of the aforementioned theory of Mörath (19) on softwoods. The general procedure was to isolate small samples of summerwood and springwood from a particular annual ring of a particular specimen of rapid growth Douglas-fir. The radial and tangential shrinkage of each sample, when dried from the fully swelled condition to the oven-dry condition, was measured. These shrinkage data were analyzed in comparison with similar shrinkage data obtained from samples containing both springwood and summerwood "attached" from the same annual ring.

From the practical standpoint the annual ring had to be relatively wide in order to facilitate the handling and measuring procedures. For purposes of ease of delineating summerwood and springwood, it was desirable also that the ring have abrupt transition. These practical requirements were met by the specimen of rapidly grown Douglas-fir wood which was selected for this study.

Sampling from the chosen annual ring was limited to a portion approximately three cm. tangentially by 65 cm. along the grain. The original air-dried piece was marked alternately along the grain into four cm. and ten cm. divisions. The four cm. lengths were designated for shrinkage and moisture content measurement, the larger section for specific gravity determinations.

It was anticipated that internal stresses due to moisture gradients in the sample during conditioning operations might affect the shrinkage measurements. To avoid as much of this as possible, the shrinkage samples were cut approximately one mm. in thickness along the grain, which is about a third or less of the average Douglas-fir tracheid length (3). For this purpose the thin sections were cut with a screw slotting saw mounted in the spindle collet of a nine-inch South Bend metal working lathe. A milling attachment vise was used to support the specimen. A random selection of thin sections from which summerwood and springwood specimens were isolated, included approximately 75% of the total. The summerwood and springwood increments were cut from these sections in such a manner as to exclude the transition zone, and were squared tangentially and radially. The remaining thin sections were trimmed to include the test ring and two consecutive annual rings on each tangential side as shown in Figure 4b. Although only the shrinkage of the test ring was needed, the additional annual rings provided the symmetrical axial shrinkage forces present in the gross wood. The resulting size of the isolated sample was approximately 1.5 mm. radially by five mm. tangentially by one mm. along the grain. The attached samples were referenced to approximately the same size as shown in Figure 4b.

Conditioning of the samples to the fiber-saturation point was accomplished in a glass humidity cell equipped with an optically flat lid. Tangential and radial measurements were made on the isolated and attached summerwood-springwood increments with the aid of a traveling tube microscope, capable of direct linear readings to five microns. Following a period of drying to the oven-dry condition, the samples were returned to another humidity cell, where dry conditions prevailed, and dimensional measurements were repeated. The shrinkage was then calculated as a percentage of the swollen dimension.

The individual oven-dry specific gravities of seven strips each of isolated summerwood and springwood were determined by obtaining the conventional O. D. weight in air followed by weighing the water displaced by each specimen when coated with paraffin. The oven-dry specific gravity was then calculated as a ratio of these two weights.

Ninety samples were selected at random from the original thin sections for the determination of moisture content at the fiber-saturation point. The summerwood and springwood increments were segregated and were subjected separately to the same conditioning treatments as the shrinkage samples. This was done to ascertain any difference in the moisture content of the two increments at the fiber-saturation point, which could account for a difference in shrinkage. However, no significant difference was found.

Results

The values given in Table 1 summarize the measurements of shrinkage for summerwood and springwood of Douglas-fir, excluding the intervening transition zone of the annual ring. The average radial shrinkage of the undisturbed annual ring tested, including the transition zone, was 4.35%. This value is not shown in the table.

From the table, the average summerwood tangential shrinkage values for the isolated and attached conditions are, 7.21% and 7.53% respectively; while the corresponding springwood tangential shrinkages are 4.81% and 7.06%. It appears that the tangential summerwood shrinkage was affected only slightly by the springwood present in the attached condition. Conversely, the summerwood apparently caused a 47% increase in tangential shrinkage of attached springwood over the corresponding free condition. Since the attached tangential shrinkage of the springwood (7.06%) is almost as large as the corresponding summerwood value (7.53%), it appears that the springwood was forced to shrink with the more dense summerwood.

Turning to a consideration of radial shrinkage, the values given in the table for the isolated and attached treatments of the springwood are, 2.39% and 1.36% respectively; while the corresponding summerwood values are 8.90% and 7.76%. In this case the attached springwood shrinkage did not approach the summerwood value as was found in the case of tangential attached shrinkage. Indeed, the

Table 1—AVERAGE SHRINKAGE OF DOUGLAS-FIR SUMMERWOOD AND SPRINGWOOD FROM FIBER-SATURATION TO THE OVEN-DRY CONDITION*

Test Condition	Tangential		Radial		T/R Ratio in Gross Wood****
	Summerwood**	Springwood***	Summerwood**	Springwood***	
	%	%	%	%	
Isolated	7.21 ± .93	4.81 ± .80	8.90 ± .99	2.39 ± 1.05	1.66
Attached	7.53 ± .60	7.06 ± .71	7.76 ± 1.68	1.36 ± 1.41	

Ratio of springwood to summerwood volumes = 2

*For original data upon which these averages are based, see (21).

**Moisture content at f.s.p. = 31.1%. Oven-dry specific gravity = 0.85.

***Moisture content at f.s.p. = 32.1%. Oven-dry specific gravity = 0.39.

****Calculated from the average of the attached tangential shrinkages of the springwood and summerwood shown in the Table, and the gross radial shrinkage (4.35%) not shown in the Table (see Figure 4).

attached value is less than the value for free shrinkage.

The effect of the summerwood-springwood interaction may be expressed mathematically, from a consideration of the elastic properties of the wood. Essentially, when dried from the green condition to the oven-dry condition, the summerwood has a greater shrinkage potential than the springwood, and after shrinking, a tangential tensile stress is present in the summerwood and a tangential compressive stress is present in the springwood. Corresponding to these stresses are strains which are a function of the elastic moduli and the stresses.

If the center portion of a very wide, flat sawn board is considered, the raised grain effect at the edges of the sample are minimized. Under these conditions the attached summerwood and springwood may be considered to shrink the same amount tangentially. From these considerations and elementary elastic theory, the tangential shrinkage of the attached summerwood and springwood may be shown to be:

$$S_T = \frac{E_0 S_1 (100 - S_3) + A_0 S_3 (100 - 1_1)}{E_0 (100 - S_3) + A_0 (100 - S_1)} \quad \text{---(1)}$$

Where:

S_T = Tangential shrinkage of gross wood in percent.

S_1 = Tangential shrinkage of the isolated summerwood in percent.

S_3 = Tangential shrinkage of the isolated springwood in percent.

E_0 = Ratio of the elastic modulus of the summerwood to the elastic modulus of the springwood, perpendicular to the grain.

A_0 = Ratio of springwood volume to summerwood volume. (Green dimension)

In the radial direction the summerwood-springwood interaction is indirect but is a function of the strains in the tangential direction and of the Poisson's Ratio U_{TR}.

(See Equation (2) below)

Where:

S_R = Radial shrinkage of the gross wood in percent.

S_2 = Radial shrinkage of the isolated summerwood in percent.

S_4 = Radial shrinkage of the isolated springwood in percent.

U_{TR} = Poisson's Ratio (strain in radial direction due to strain in tangential direction) subscripts 1 and 2 refer to the summerwood and springwood respectively.

Other symbols as in equation 1

As the T/R ratio is S_T/S_R:

(See Equation (3) below)

From empirical equations (1, 28) relating the elastic modulus to specific gravity and moisture content, E_0 is independent of moisture content. U_{TR} does vary slightly with moisture content (6, 14) but the variation is nearly linear and the values at 12% may be used effectively over the entire moisture content range.

It is hazardous to attempt a check on the validity of equation 3 using the shrinkage obtained in the present study of Douglas-fir. Although good agreement is obtained between the theoretical and observed T/R ratios the check is of doubtful value due to the large variation of individual shrinkage values as evidenced by the large standard deviations of Table 1. Also the data reported in the literature is generally incomplete as far as a check for equation 3 is concerned. Therefore, equation 3 is presented without experimental confirmation. Of course, its theoretical validity is limited to conditions within the elastic limit of the summerwood and springwood of woods having an abrupt transition between springwood and summerwood. Also it describes the shrinkage away from the edges of the sample where the stresses may be considered as pure compression and tension. Near the edges the stresses become more shearing in nature.

As an illustration of the phenomena described by equation 3, consider the hypothetical case of a wood with the following characteristics:

1. Isolated summerwood volumetric shrinkage = 15%
2. Isolated springwood volumetric shrinkage = 6%
3. $A_0 = 2$
4. $(U_{TR})_1 = (U_{TR})_2 = 0.15$ (13)

Doyle, Drow and McBurney (6) find little, if any, correlation between Poisson's Ratios and density which justifies setting $(U_{TR})_1 = (U_{TR})_2$.

In order to select a value of E_0 consistent with the shrinkage assumed, the ratio of the volumetric shrinkages may be taken as the ratio of the specific gravities of the summerwood and springwood as has been shown by Stamm (27). Thus, if g_1 and g_2 represent the specific gravities of the summerwood and springwood respectively:

$$g_1/g_2 = 15/6 = 2.5$$

As the ratio of the elastic moduli (E_0) varies as a power of g_1/g_2 (1):

$$E_0 = (g_1/g_2)^n$$

Estimating the power n to be the same as the power for the fiber stress at the proportional limit (1):

$$E_0 = 2.5)^{2.5} = 10$$

Neglecting longitudinal shrinkage, the following expressions are approximately true.

$$\frac{S_1 + S_2 = 15\%}{S_3 + S_4 = 6\%} \quad \text{----------(4)}$$

If all the above values are held constant and S_1, S_2, S_3, and S_4 are varied within the limitations of equation 4, we are, in effect, holding the mechanism of summerwood-springwood in-

$$S_R = \frac{[E_0 (100 - S_3) + A_0 (100 - S_1)] [S_2 + A_0 S_4] - A_0 [S_1 - S_3] E_0 (U_{TR})_2 (100 - S_4) - (U_{TR})_1 (1 - S_2)]}{[E_0 (100 - S_3) + A_0 (100 - S_1)] [1 + A_0]} \quad (2)$$

$$T/R = \frac{[E_0 S_1 (100 - S_3) + A_0 S_3 (100 - S_1)] [1 + A_0]}{[E_0 (100 - S_3) + A_0 (100 - S_1)][S_2 + A_0 S_4] - A_0 [S_1 - S_3] [E_0 (U_{TR})_2 (100 - S_4) - (U_{TR})_1 (1 - S_2)]} \quad (3)$$

teraction constant while varying any other differential shrinkage mechanisms that may be present.

Several sets of values of S_1, S_2, S_3 and S_4 have been substituted into equation 3 and the results are shown in Table 2.

The T/R ratio obtained from case 1 of Table 2 is due entirely to the Mörath summerwood-springwood mechanism, while the other cases include mechanisms in addition to that of Mörath. Column 8 of Table 2 gives the percent of the deviation from a T/R ratio of unity that may be attributed to the Mörath mechanism, based on equation 3 and the assumptions used in setting up the hypothetical problem. That is in case 1, the percent due to the Mörath mechanism $= \frac{2.017-1}{2.017-1} \times 100 = 100\%$ and in case 2, the percent due to the Mörath mechanism $= \frac{2.017-1}{3.329-1} \times 100 = 43.7\%$, etc. For this hypothetical wood the effectiveness of the Mörath mechanism in explaining the T/R ratio of the gross wood is particularly sensitive to the T/R ratio in the isolated summerwood (S_1S_2). An attempt was made to select shrinkage values and elastic constants for the hypothetical wood that were reasonable. As the T/R ratio in the summerwood is generally near unity, perhaps cases 3, 5, and 6 are the most reasonable. However, it should be noted that in the event the T.R ratio in the summerwood becomes less than unity, as was observed as the most probable condition in the present study of Douglas-fir (Table 1), the summerwood tends to compensate the differential shrinkage of the springwood and the Mörath mechanism explains a very substantial amount of the observed T/R ratio (case 7 of Table 2).

Any conclusions based upon Table 2 would lack generality. From equation 3 it is found that as the ratio of the summerwood strength to the springwood strength increases, the Mörath mechanism increases in importance, but the importance decreases as the relative volume of springwood increases. Thus the efficacy of the springwood-summerwood interaction on the observed differential shrinkage is dependent upon the species and particular sample selected for study. However, for temperate zone woods it may be reasonable to assume a prominent role for the Mörath mechanism.

The general conclusions drawn from equation 3 are at variance with the previously mentioned objections to the Mörath hypothesis raised by Ritter and Mitchell. Equation 3 predicts that the effects of mechanisms other than that of Mörath on the isolated summerwood and springwood T/R ratios (cases 2–7 of Table 2) do not necessarily have an overpowering influence on the observed differential shrinkage of the gross wood (column 6 of Table 2). The data reported by Ritter and Mitchell indicate that the tangential strain (a good approximation to the strain is attached minus detached tangenial shrinkage) in the springwood is approximately six times the tangential strain in the summerwood due to the interaction of the two increments. This gives a value of $E_0A_0 = 6$ (obtained by use of equation 1), which is nearly the value used in the calculation of the results of Table 2. However, they do not report values for the relative volume of springwood or the isolated radial shrinkages of the summerwood and springwood. Such values might have strengthened their postulation of a minor role for the Mörath mechanism.

Perhaps the utility of equation 3, if valid, is not in assessing the proportion of the T/R ratio to the Mörath mechanism but as a guide to a more quantitative analysis of the unexplained mechanisms which are affecting the differential shrinkage within the summerwood and springwood. It may be possible to derive expressions for S_1, S_2, S_3 and S_4 of equation 3 in terms of specific gravity, ray volume, pit area and so forth, and obtain a usable general expression for the differential shrinkage of any wood.

Summary

All of the prominent theories of wood shrinkage are based upon the commonly accepted "fringe micellar theory" of cell wall structure. The explanation of differential transverse shrinkage has been related to the location of cells (springwood and summerwood, and ray cells), to the features of the cell wall structure (fibril angle and pits), and to the distribution of the middle lamella. Due to the complexity and diversity of structure found in wood, it is believed that the mechanism of greatest influence depends upon the wood under consideration, and that this mechanism is modified by one or several of the other mechanisms. A general equation is proposed which relates the T/R ratio of the gross wood to the isolated shrinkages, elastic constants, and volume of the summerwood and the springwood. From tests conducted on Douglas-fir wood it was found for the particular samples studied that the summerwood-springwood theory of Mörath largely explained the observed differential shrinkage of the gross wood, but that other mechanisms were evident within the isolated summerwood and springwood.

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(Continued on page 86)

Table 2—THE INFLUENCE OF THE SUMMERWOOD–SPRINGWOOD INTERACTION THEORY OF MORATH AND OTHER DIFFERENTIAL SHRINKAGE MECHANISMS[1] ON THE T/R RATIO OF THE GROSS WOOD AS PREDICTED BY EQUATION 3 FOR A HYPOTHETICAL WOOD

	Assumed Shrinkages of Isolated Ring Components				T/R Ratio of Attached Ring Components Calculated from Equation 3	Deviation of T/R Ratios of Column 6 From Unity	Percent[3] of Deviation (Column 7) Due to Mörath
	Summerwood $S_1+S_2=15\%$[2]		Springwood $S_3+S_4=6\%$[2]				
	Tang. S_1	Radial S_2	Tang. S_3	Radial S_4			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Case 1	7.5%	7.5%	3.0%	3.0%	2.017	1.017	100.0%
Case 2	8.5	6.5	4.0	2.0	3.329	2.329	43.7
Case 3	8.0	7.0	4.0	2.0	2.794	1.794	56.7
Case 4	8.0	7.0	3.0	3.0	2.349	1.349	75.4
Case 5	7.75	7.25	4.0	2.0	2.569	1.569	63.8
Case 6	7.5	7.5	4.0	2.0	2.367	1.367	73.1
Case 7	7.0	8.0	4.0	2.0	2.019	1.019	98.1

[1] The existence of other mechanisms is indicated by cases of column 1 which show T/R ratios within the isolated summerwood (column 2 divided by column 3) and/or the isolated springwood (column 4 divided by column 5) which are other than unity.

[2] To vary only the mechanisms other than that of Mörath, the specific gravities of the summerwood and springwood were held constant (and thus the strength ratio E_0) for all cases of column 1. Therefore (neglecting longitudinal shrinkage) the area shrinkages (column 2 + column 3 and column 4 + column 5) are also constant.

[3] Calculated as the ratio of the deviation (column 7) of case 1 to the deviation (column 7) of the case in question. As the T/R ratio for isotropic shrinkage is unity, the deviations represent the differential portion.

Effect of Formaldehyde Treatments Upon the Dimensional Stabilization of Wood[1]

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The action of formaldehyde on wood under different conditions is presented. Formaldehyde vapor in the presence of a strong mineral-acid catalyst is shown to stabilize the dimensions of wood to a high degree through an acetal cross-linking reaction. The wood, however, is embrittled to such an extent by the required acid that dimensional stabilization by this means does not appear commercially practical. The findings show, however, that the principle of dimensional stabilization by cross linking is sound. Other cross linking agents that react under less drastic conditions will have to be sought.

Introduction

FORMALDEHYDE IS KNOWN to form intramolecular acetals between the hydroxyl groups on carbon atoms 1 and 2, and 4 and 5 of sugars (*2, 5*).[3] Since the 1 and 4 hydroxyls, each of which is involved in one of the acetal-forming reactions, are not present in polysaccharides, such acetals cannot form in cellulose or wood. There still remains the possibility of intermolecular acetal formation. This has been used to explain the modifying action of formaldehyde on the water absorption (or so-called swelling), dye absorption, solubility in solvents for cellulose, wet strength, launderability, and wrinkle resistance of cellulose in the form of fibers, paper, and fabric (*1, 3, 4, 14*). Small amounts of divinyl benzene, when added to vinyl benzene before polymerization, give a polystyrene with reduced swelling capacity (*13*). This effect has been ascribed to the formation of occasional cross links. One would expect acetal linkages that bridge swelling units, even when present in very small amounts, to have similar pronounced effects on the swelling of cellulosic materials.

Present dimension-stabilizing methods for wood require large amounts of chemical, since they depend on a bulking of cell walls (*12*). The greater this bulking, as measured by the increase in the dimensions of oven-dry wood after treatment, the greater the stabilization. To obtain a high degree of dimensional stability with resins requires the deposition of 30 percent (dry-wood weight basis) of resin within the cell walls (*8, 10*). Similar stabilization by acetylation requires a 20-percent weight increase (*11*). It is thus of practical importance to determine whether acetal cross links can be introduced into wood in such a way as to impart to it a high degree of dimensional stability with the use of only small amounts of chemical.

[1] Research sponsored by the Office of Naval Research under Order No. NAonr 42-47. Presented at the 12th International Congress of Pure and Applied Chemistry, New York, Sept. 14, 1951.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] The italic figures in parentheses refer to Literature Cited at end of this report.

Treatment with Formalin

Matched, air-dry cross sections of Sitka spruce (1/8 inch in the fiber direction) were soaked in water, 40 percent formalin, or 40 percent formalin containing 2 percent of concentrated hydrochloric acid. They were then heated to 90° C. for 4 hours, washed, and oven dried. Although the specimens swelled more upon digesting in formalin than in water, the shrinkage during oven drying was somewhat more for the specimens digested in formalin and considerably more for those digested in acidified formalin than for those digested in water, as is shown in table 1. This is presumably due to the removal of cell-wall components by the formalin, especially when acidified.

After being oven dried, the specimens were swollen in water. Table 1 shows that the subsequent dimension changes were somewhat more for the formalin-treated specimens than for the controls. Similar experiments with other mineral and organic acids in various concentrations heated to various temperatures for various periods of time gave similar results. It is thus apparent that the treatment of wood with formalin under these conditions has no beneficial effect upon the subsequent dimensional stability of wood, even though temperatures and acidities were used that proved to be adequate for cross linking with dry formaldehyde.

Cross sections of spruce were also soaked in solutions of formalin in morpholine, which is an excellent swelling agent for wood, and oven dried. The antishrink efficiency for these specimens

$$\text{ASE} = \left[1 - \frac{\text{swelling of treated specimen (percent)}}{\text{swelling of control (percent)}}\right] \times 100$$

was determined on the basis of the change in dimensions between the oven-dry and the water-swollen condition. It is plotted in figure 1 against the morpholine content of the treating solution. An optimum antishrink value resulted at about 25 percent of morpholine.

In all cases, the treatment increased the dimensions of the oven-dry wood. This increase is shown in figure 2 to be inversely proportional to the subsequent swelling in water, as is the case for other treating agents that stabilize the dimensions of wood by bulking the fiber. It is thus apparent that this dimensional stabilization is due to bulking of the fiber rather than to cross linking. Volumetric swelling in all of these cases is reduced by an amount equal to the volume of the bulking agent in the fiber (*12*). The bulking is evidently caused by a high-boiling complex formed between morpholine and formaldehyde. The formation of this complex can be demonstrated by heating the solution of morpholine and formalin alone. The optimum antishrink efficiency shown in figure 1 presumably results from an optimum complex formation occurring at a morpholine content of 25 percent under heating conditions that cause a loss of part of the formaldehyde. Formalin alone gives no bulking and no antishrink efficiency, because any polymer of formaldehyde

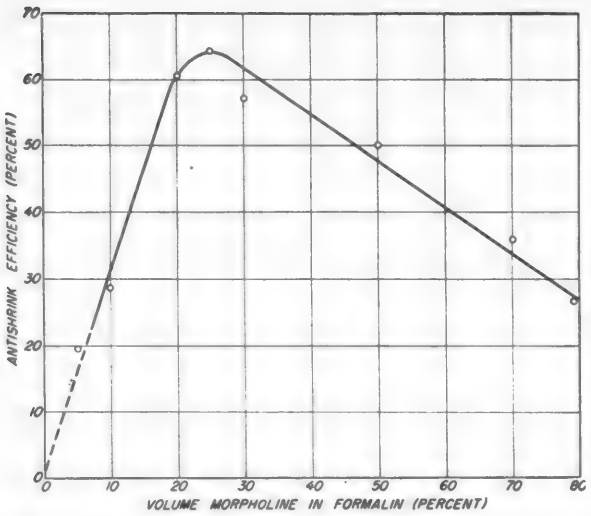

Figure 1.—Anti-shrink efficiency of cross sections of Sitka spruce treated with solutions of various concentrations of morpholine in formalin.

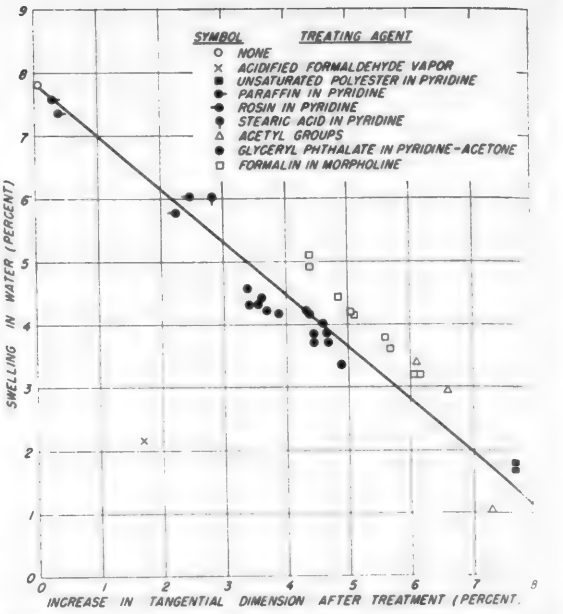

Figure 2.—Relationship between degrees of bulking and corresponding swelling in water of Sitka spruce cross sections subjected to various treatments.

that might be formed within the fibers is rapidly lost due to volatilization during the drying process.

When specimens of wood treated with solutions of formalin in morpholine are subjected to a number of alternate water-soaking and oven-drying cycles, they gradually lose their antishrink efficiency due to leaching and volatilization of the morpholine-formaldehyde complex. Treatment of wood with such solutions would hence not be a practical means of reducing swelling and shrinking.

Treatment with Formaldehyde Vapor

It has been reported that formaldehyde vapor is more effective in reducing the hygroscopicity of gelatin than is formalin (*6*). In following this lead, experiments were made on the effect of formaldehyde vapor on wood. The vapor was generated by heating paraformaldehyde in the bottom of a sealed jar in which the specimens were suspended. Temperatures as high as 160° C. had little effect upon the dimensional stability of the cross sections. When the wood was heated in the presence of formaldehyde vapor and small amounts of mineral-acid vapors, however, antishrink efficiencies as high as 72 percent were obtained. This high antishrink efficiency is accompanied by only one-fourth of the increase in the tangential dimension of oven-dry wood that would take place if the stabilization were due to bulking. Thus, in figure 2 the datum for the formaldehyde-treated wood is the only one that lies significantly off the curve. Stabilization by this method is therefore not due to a bulking action.

Effect of Moisture: The fact that a high degree of dimensional stabilization was attained with acidified formaldehyde vapor and none was obtained with acidified formalin indicates that an excess of moisture or swelling is detrimental to the reaction. Table 2 shows that there is an optimum desirable moisture content for the wood. The optimum moisture content decreases with increasing temperature; thus, at 100° C., an antishrink efficiency of 78 percent was obtained with oven-dry wood. The gain in weight due to reaction with formaldehyde was, in this case, only 4.2 percent. To be effective, the formaldehyde has to diffuse into the intimate structure of the wood. Diffusion is enhanced either by treating at high temperatures or by slightly preswelling the wood.

Since diffusion in the transverse direction is much slower than that in the longitudinal direction, it was expected that the optimum moisture content of sheets of veneer would be higher than that of thin cross sections of wood. Under the same conditions used for the cross sections (table 2), the optimum stabilization was obtained when the sheets of veneer ($\frac{1}{16}$ inch thick) were conditioned at 65 percent relative humidity (to about 12 percent moisture content).

Moisture in excess of that required for the optimum stabilization may be harmful for the following reasons:

1. In the acetal reaction between wood and formaldehyde, water is a reaction product; consequently, the presence of excess moisture may retard the reaction.

2. Formaldehyde reacts with water to form a hydrate. Formalin has been shown by spectroscopic means (*7*) to have very few free carbonyl groups, which are necessary for the acetal reaction.

Table 1.—Effect of digesting thin cross sections of Sitka spruce in water, formalin, and acidified formalin at 90° C. for 4 hours, washing and drying, and again soaking in water upon the tangential dimensions of the sections

Specimens digested in	Original air-dry dimension	Swollen dimension after digestion	Oven-dry dimension after washing and drying	Swollen dimension after second soaking	Subsequent swelling from oven-dry to water-swollen condition
	Mm.	Mm.	Mm.	Mm.	Percent
Water	50.40	54.16	48.88	54.10	10.7
Formalin	50.43	54.86	47.97	54.13	12.9
Formalin containing 2 percent of concentrated hydrochloric acid	50.42	54.74	44.56	53.20	19.3

Table 2.--Effect of the initial moisture content of wood on the antishrink efficiency resulting from treatment overnight of thin spruce cross sections with acidified formaldehyde vapor at 60° C.

Moisture content of wood	Antishrink efficiency after treatment
Percent	Percent
2.0	25
5.5	68
7.5	68
12.0	62
20.0	52

Table 3.--Stabilization of thin spruce cross sections by separate treatments with formaldehyde vapor and acid. All specimens exposed to formaldehyde vapor overnight at 60° C.

Acid treatment	Antishrink efficiency
	Percent
None	20
Exposed to 0.07 gm. nitric acid per 4 gm. wood at 50° C.	61
Exposed to 0.07 gm. nitric acid per 4 gm. wood at 60° C.	66

3. Formaldehyde, in the presence of excess moisture, swells wood to such an extent that cross links cannot bridge swelling units.

Effect of Acid Catalysts: Numerous experiments have shown that the greatest dimensional stabilization is obtained with formaldehyde when small amounts of concentrated nitric or hydrochloric acid are sprayed into the reaction chamber to catalyze the reaction. The acid may be sprayed in either immediately or after the wood has taken up its equilibrium amount of formaldehyde vapor (table 3).

Weaker acids, such as sulfurous acid and formic acid, were ineffective as catalysts, even though formic acid is excellent for swelling and opening up the structure of wood.

The amount of nitric or hydrochloric acid required is difficult to determine. It seems to depend upon such factors as the quantity of wood, the ratio of container volume to quantity of wood, the efficiency of stirring, and even on the material of which the container is made. It has been observed that the stabilization is more complete in a glass than in a stainless-steel container when the same amount of acid is used in each.

Table 4 gives the antishrink efficiency obtained upon treatment of thin spruce cross sections simultaneously with formaldehyde vapor and nitric acid at various temperatures. The data indicate that the percentage gain in weight due to take-up of vapor, both before and after heating to remove the unreacted excess of formaldehyde, is independent of the amount of acid catalyst used at each temperature but increases with increasing temperature. The antishrink efficiency, however, increases with increasing amounts of catalyst used. It thus appears that the catalyst in all of the concentrations used causes only a small part of the adsorbed formaldehyde to react with the wood. The remaining portion of the adsorbed formaldehyde is presumably present as a polymer—perhaps paraformaldehyde, since it has been observed that on heating formaldehyde vapor by itself in a closed bomb a white film is found on the walls that has the melting point and solubility of this formaldehyde polymer. At a given temperature, the sum of the formaldehyde reacting with the wood and the formaldehyde present as a polymer is evidently constant. With varying conditions of acidity, only the proportion of the formaldehyde held in the two ways changes, and with this change, the degree of stabilization changes. With constant acidity, the antishrink efficiency reaches a maximum at 60° C. At higher temperatures, excessive reduction of nitric acid by formaldehyde occurs.

A study was made to determine the acidity conditions needed to get good dimensional stabilization. To do this it was necessary to buffer the adsorbed water in the air-dry wood. This was accomplished by soaking spruce cross sections for 8 hours in various buffer solutions (pH 4.9, 4.1, 3.2, 2.9, and 2.3) and allowing them to come to swelling equilibrium under nondrying conditions. The specimens were then weighed, air dried, and weighed again. To correct for the concentration of the buffers in the wood during air drying, portions of the buffer solutions were concentrated to the same degree, and the pH was determined. The values were 4.7, 4.0, 3.1, 2.0, and 1.2, respectively. Thus, concentrating the buffers reduced the pH of the first three solutions but slightly. The last two, however, had pH values appreciably lower than the original values. The pH values of the adsorbed water obtained in this way were further checked by leaching some of the dried sections containing concentrated buffer with definite amounts of water to cause different degrees of dilution. The pH values of these diluted extracts were determined and compared with similar dilutions of concentrated buffer solutions. The agreements were reasonably good, which indicated that the pH of air-dry buffered wood can be approximated reasonably well in this way.

The buffered specimens were exposed to formaldehyde vapor at 60° to 85° C. for 6 hours and were then washed in water and dried. Swelling and shrinking measurements showed that only under the most acidic conditions, pH 1.2, was there a measurable dimensional stabilization (8 percent antishrink efficiency for the 60° C. specimens and 12 percent for the 85° C. specimens). The data thus indicate that in order to obtain worthwhile dimensional stabilization, the pH of the adsorbed water has to be below a value of 1.0.

Boron trifluoride has been used as a promoter in certain reactions requiring acid catalysts. It was tried in these studies and found effective only under acidic conditions that cause degradation of the wood.

From tables 3 and 4, it will be noted that formaldehyde vapor, unlike formalin, imparts some antishrink efficiency to wood even in the absence of an acid catalyst. If all of the formaldehyde taken up by the wood is in the form of a formaldehyde polymer within the cell-wall structure, it will be sufficient to account for the experimental antishrink values on the basis of its bulking effect. Repeated swelling and shrinking measurements, however, will eliminate this stabiliza-

Table 4.--Weight gain and antishrink efficiency obtained on stabilizing thin spruce cross sections simultaneously with formaldehyde vapor and various amounts of nitric acid at various temperatures

Treating temperature	Amount of nitric acid in treating bomb	Weight gain due to vapor take-up during treatment	Dried at 80° C., 16 hours	
			Final weight gain	Antishrink efficiency
° C.	Cc.	Percent	Percent	Percent
50	0.05	12.3	3.1	42
50	.10	12.4	3.1	47
50	.20	13.8	4.1	55
		Av. 12.9	Av. 3.4	
60	.05	17.7	5.0	57
60	.10	17.2	4.7	61
60	.20	16.5	3.8	63
		Av. 17.1	Av. 4.5	
70	.00	18.7	5.2	21
70	.10	19.0	5.9	57
70	.20	16.3	5.5	60
		Av. 18.0	Av. 5.5	
85	.05	24.0	7.0	35
85	.10	22.5	7.4	49
85	.20	21.2	6.8	53
		Av. 22.6	Av. 7.1	

tion obtained under nonacidic treating conditions.

Evidence of Cross Linking: The following observations suggest the formation of acetal cross links when wood is exposed to acidified formaldehyde vapor:

1. Gains in weight of as little as 4.2 percent can result in at least four times the dimensional stabilization that can be accounted for on the basis of bulking.

2. The formaldehyde reaction reduces the degree to which the wood can swell rather than the degree to which it can shrink, as in the bulking methods.

3. The presence of acetal cross links should be effective in reducing the swelling not only in water but in other good wood-swelling liquids. The data in table 5 show this to be true. The reduced swelling in 18 percent alkali further shows that the reaction produced is stable under alkaline conditions. Acetals are known to be stable towards alkali.

4. If acetal groups are responsible for the reduced swelling, then on treating with a reagent that is known to hydrolyze acetal groups, the wood should swell to the degree it would have swollen in the absence of the formaldehyde treatment (table 6). Thus, on immersing the water-swollen specimen in 12 percent hydrochloric acid, the control swelled slightly, whereas the formaldehyde-stabilized specimen swelled by a larger amount but to approximately the same dimension as that of the control. The acid apparently hydrolyzed the acetal cross links, thus permitting the swelling units to separate by their normal amount.

Effectiveness of Cross Links: The determination of the concentration of acetal cross links in formaldehyde-treated wood is difficult for two reasons. First, wood contains groupings that give tests for formaldehyde. Second, not all of the gain in weight on treatment is due to chemically combined formaldehyde. Some is due to the presence of formaldehyde polymer. This was strikingly revealed by the ability of a treated cross section to stop the growth of *Polyporus versicolor* when suspended 1 centimeter above the culture. Apparently, the residual polymer had sufficient vapor pressure to exert its toxic influence.

An indication of the concentration of cross links required to achieve some dimensional stability was obtained in the following way: It was observed that when cross sections containing 6 percent of moisture were exposed to chloral vapors in the absence of an added acid catalyst, antishrink efficiencies of about 30 percent were obtained. The wood was darkened and embrittled just as if an acid catalyst had been used but presumably because of a slight oxidation of chloral to trichloroacetic acid. On swelling in water, it behaved like formaldehyde-stabilized wood; the reduction in swelling was due essentially to a reduction in water-swollen dimensions rather than to an increase in oven-dry dimensions. Furthermore, when the wood was treated with 12 percent mineral acid, the stabilization was eliminated. Thus, it is likely that the chloral participated in an acetal reaction and did this by bridging swelling units. The chlorine content of the treated wood (corrected for naturally occurring chloride) was found to be 0.3 percent. The equivalent content of trichloroacetic groups (Cl_3C-CH) was 0.4 percent. Thus, on adding 0.4 percent of this grouping to wood, an antishrink efficiency of about 30 percent was obtained. To achieve the same stabilization with resins would require about 12 percent of resin.

Strength Properties of Formaldehyde-stabilized Wood: Dimensional stabilization of wood with acidified formaldehyde vapor is accompanied by an embrittlement of the wood. Figure 3 shows that the loss in toughness is directly proportional to the antishrink efficiency. With weak acids or small quantities of acid, or when the temperature is lowered, the loss in toughness is decreased. The antishrink efficiency, however, is also decreased. Similar reductions in toughness are obtained when wood is treated only with acid; thus, the embrittlement must be due to hydrolysis of the cellulose fibers. With resin-treated wood, embrittlement seems to be caused by an increased rigidity of the entire system. Whereas resin-treated wood has only slightly reduced abrasion resistance, the formeldahyde-stabilized wood has extremely low abrasion resistance; it may be reduced to as little as one-tenth that of the control. Thus, the material would have poor scuff and weathering resistance. Accordingly, the hydrolysis accompanying the dimension-stabilizing reaction makes the commercial use of formaldehyde-stabilized wood appear impractical.

The reaction of wood with other aldehydes (acetaldehyde, benzaldehyde) was studied. Although some stabilization was obtained, the required acid catalyst brought about the previously mentioned degradation.

Discussion and Conclusions

The swelling and the hygroscopicity of wood can be materially reduced by treating the wood with formaldehyde only under relatively dry conditions using a strong mineral acid catalyst. This finding may at first appear to be at variance with the findings of other investigators who studied the action of formaldehyde on cellulose (*3, 4*). This is not the case. Although signifi-

Table 5.--Swelling of normal and formaldehyde-treated cross sections of spruce in different liquids

Specimen	Swelling in --			
	Water	18 percent sodium hydroxide	Morpholine	Pyridine
	Percent	Percent	Percent	Percent
Control (no treatment)	9.7	14.1	13.2	12.6
Formaldehyde-treated wood	3.3	5.7	.3	5.3

Table 6.--Effect of mineral acid on the permanence of formaldehyde stabilization

Specimen	Original tangential dimension	Water-swollen dimension	Antishrink efficiency	Swollen tangential dimension after immersion of specimen in 12 percent hydrochloric acid
	Mm.	Mm.	Percent	Mm.
Untreated control	36.50	38.93	0	39.17
Wood treated with acidified formaldehyde vapor	36.49	37.59	59	39.20

cant increases in wet strength and reductions in water absorption have been attained using formalin and relatively weak acid catalysts, none of these investigators have obtained sizable reductions in hygroscopicity. A few cross bonds at junctions between cellulose fibers could accomplish the effects observed by these investigators by limiting the dispersion of the fibers that occurs above the fiber-saturation point (*9*). These limited cross bonds, however, would not prevent the adsorption of water within the noncrystalline zones of each cellulose fiber. The extent of cross bonding would have to be much more complete to reduce significantly the swelling of the fiber itself or the hygroscopicity of the cellulose as a whole.

Some Objectives Met

Goldthwait (*3*) used formaldehyde in the relatively water-free state and a mineral acid catalyst to treat mercerized and unmercerized cotton fabrics. The catalyst was of about the same order of concentration as was used in this research on wood. He reports a decrease in moisture regain (presumably at 65 percent relative humidity) of 1 percent. This corresponds to an antishrink efficiency of only 15 percent. This reduction is evidently sufficient to give profound reductions in dye absorption and significant increases in rot resistance. A relatively smaller amount of cross linking should be required to prevent the internal adsorption of large dye molecules compared to the amount of cross linking needed to prevent the adsorption of water. Likewise, under these conditions, the penetration of the usually large enzyme molecules secreted by decay organisms should be hindered. Studies of resin treatment and acetylation of wood have previously shown that when the antishrink efficiency of the wood is reduced below 20 percent, significant decay resistance is imparted to the wood (*10, 11*). It is thus evident that these and other objectives of the textile and the paper manufacturer, such as the development of wet-strength creaseproofness and reduced imbibition of liquids, can be met by limited cross bonding.

Treatment Impractical

Goldthwait (*3*) found that a 10 to 15 percent loss in breaking strength of fabrics he tested accompanied the development of the 15 percent antishrink efficiency. This is of the same order as the loss in toughness accompanying the cross bonding of wood to attain the same antishrink efficiency (fig. 3). It would not pay to treat wood to attain such small antishrink efficiencies. Unfortunately, when the amount of catalyst used is increased to attain a degree of cross bonding necessary to give antishrink efficiencies of 60 to 70 percent, the loss in toughness is 60 to 70 percent (fig. 3). This, together with the loss in abrasion resistance, makes the dimensional stabilization of wood with formaldehyde in the presence of an acid catlyst quite impractical.

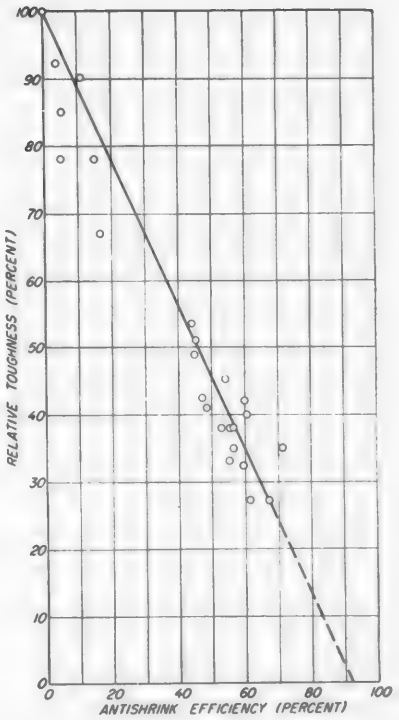

Figure 3.—Relationship between relative toughness and anti-shrink efficiency of formaldehyde-stabilized wood.

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Factors Affecting the Expansion of Hard Maple Flooring[1]

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Paper describes tests designed to provide information on the expansion of hard maple flooring in service. As part of test, modified joint which provided true vertical surfaces and intimate contact of strips was found to provide superior resistance to buckling.

FLOORS, DURING the early days of our country's development, usually consisted of adzed sections of softwood logs laid edge to edge to form a hewn or "puncheon" floor. With the advent of sawed lumber, however, less importance was placed upon the ease with which flooring material could be worked and more attention was given to the selection of species which would provide better resistance to wear.

As the early builder gained experience with the wear resistance of the various species of wood, he discovered that, in general, the wearing qualities of wood floors could be improved by the use of the more dense species. For school, gymnasium, ballroom, post office, and other floors subjected to extreme conditions of wear, the wood most often selected was hard maple *(Acer Saccharum)*. This dense species provided a hard, smooth-textured, long wearing surface and has remained, throughout the years, the outstanding flooring wood where high resistance to abrasion is required.

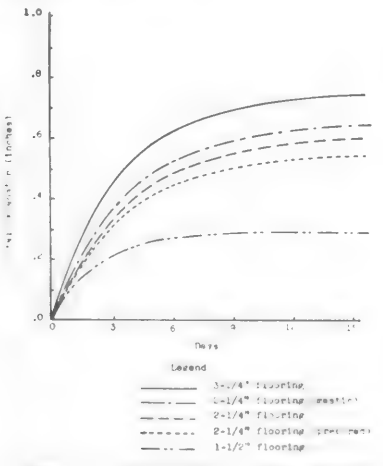

Figure 1.—Comparison of the expansion of five flooring panels following a 15-day conditioning period at 138° F. and 85 percent relative humidity.

[1] Presented at meeting of Forest Products Research Society, Northeast Section, December 4-5, 1952, at New York City.

The use of dense woods as flooring material, however, is not without its problems. In general, shrinkage and swelling of the heavier woods is greater than the dimensional changes which occur in the lighter species under identical humidity conditions. This tendency to shrink and swell, unless controlled or provided for in the construction of the floor, results in excessively large cracks between the flooring strips under low humidity conditions, or buckling of the floor when high humidity prevails.

In an effort to acquaint builders with the factors involved in laying a tight, sound, hard maple floor, the Maple Flooring Manufacturers Association has sponsored a research program designed to provide information on the expansion of hard maple flooring in service. The initial investigation, conducted at the laboratory of the Timber Engineering Company, was specifically concerned with the relative expansions of 1½, 2¼ and 3¼ inch hard maple flooring subjected to humidity conditions which were to produce an equilibrium moisture content of 15 percent. Secondary considerations were the expansion retarding effects of such techniques as preboring and the use of a mastic vapor barrier between the finish floor and the subfloor.

Fabrication and Conditioning of Test Panels

Since this initial investigation was considered basic to the major research program now in progress, a study of the variables mentioned previously was made on five square panels, four feet on a side. These panels were constructed in accordance with accepted framing procedures and consisted of two-by-six inch Southern yellow pine joists spaced 16 inches on center and bridged at the middle of the panel. One by six inch Southern yellow pine subflooring was laid at 45 degrees with the joists and covered with a standard 30 pound building paper. The finish floor of hard maple was then applied at right angles to the joists and nailed with 2¼ inch cut flooring nails at each joist crossing.

Three panels were covered with 1½, 2¼ and 3¼ inch flooring widths respectively. A fourth panel consisted of 2¼ inch flooring prebored at each joist to prevent splitting of the tongue when the nail was driven, and panel five was covered with 2¼ inch flooring over a $\frac{3}{32}$ inch coat of cold mastic.

With an initial moisture content of nine percent for the finish flooring,

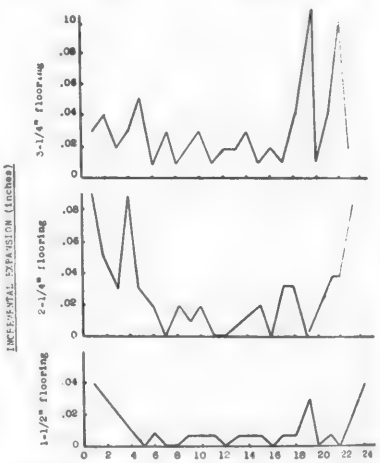

Figure 2.—Expansion of 1½, 2¼, and 3¼-inch flooring by 2-inch increments over a panel width of four feet.

the panels were subjected to a temperature of 138° F. and a relative humidity of 85 percent. Measurements of total and incremental expansion across the grain were then made at three-day intervals throughout a period of 15 days. Following the conditioning period, measurements of flooring movement were taken along each panel edge by measuring the displacement of two-inch graduations from mated marks along the outside joists.

Comparative expansions of the five test panels throughout the conditioning period are illustrated by the curves in Figure 1. An examination of these data shows substantial increase in overall expansion as the width of the flooring strips increases. Total expansion of the 2¼ inch strips, for instance,

was found to exceed the expansion of 1½ inch strips by approximately 100 percent, while expansion of 3¼ inch flooring surpassed that of the 1½ inch material by 130 percent. No significant difference could be noted in the expansion of the panel having a mastic vapor barrier when comparison was made with the 2¼ inch flooring laid over waterproofed building paper. Preboring, however, did result in a reduction in over-all expansion of approximately 10 percent although, for this small number of panels, a 10 percent difference was not considered significant.

The expansion curves presented in Figure 1 tend to indicate a definite relationship between the number of tongue and groove joints in a given floor width and the maximum expansion which may occur under high humidity conditions. The fact that expansion of the flooring was shown to increase with the width of the strip indicates that for a flooring strip somewhere between 0 and 1½ inches in width, panel expansion would be practically nonexistent. For wider strip widths, however, the number of nails in any given panel is reduced and their subsequent restraining ability is not sufficient to prevent movement.

A second factor which contributed to a smaller over-all expansion for panels having narrow flooring strip widths was the tendency for slight compression failures to occur in the upper portion of each tongue and groove joint as the flooring expanded. The tongue and groove design of the flooring used in these tests was such that actual contact between strips occurred only along a small area of the joint near the flooring surface. This area proved insufficient to withstand the expansion forces of the flooring without some degree of compression failure. Since a greater percentage of actual fiber compression took place in the panels having the greater number of joints, it was understandable that these panels should also exhibit a smaller over-all expansion.

In addition to total expansion measurements, each panel was also measured for incremental expansion by the change in distance between 2 inch increments across the panel surface. Graphs of these expansions for the three widths of flooring are presented in Figure 2. These graphs also show the increase in expansion as flooring strip width increases. Although an examination of these expansion values shows no increase in size for some increments, it was expected that variations in density of the flooring strips would result in expansion of the more dense strips and compression of the lighter, weaker pieces. A tendency toward minimum expansion in the central portion of the panel where nail resistance was greatest, and greater expansion at the extremes where nail resistance decreased, was also apparent.

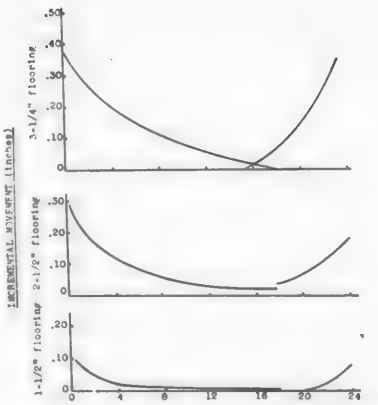

Figure 3.—Movement of 1½, 2¼, and 3¼-inch flooring by 2-inch increments over a panel width of four feet.

Although incremental expansion values for the three flooring sizes proved erratic because of the variations in compression which occurred at the joints, flooring movement graphs displayed a definite curvilinear relationship between location in the panel and movement of calibrations along the panel edge. These curves, illustrated in Figure 3, show maximum strip movement toward the panel edges where the restraining nails are fewer in number and practically no movement throughout the central portions of the panels where the cumulative nail resistance and degree of joint compression were sufficient to prevent expansion.

Since movement measurements were taken from the same edge of each panel, i.e. with the flooring nail slope upward from left to right, a definite skewness in the direction of the nail slant was apparent for each curve. This skewed condition was attributed to the greater holding power of the flooring nails when loaded in the direction of the nail slope on one half of the panel and a lower nail resistance when loaded in the opposite direction on the other half.

Lateral Nail Resistance Tests

Further information on the relative lateral resistance of 2¼ inch cut nails, with and against the nail angle, was obtained from a series of tests on single nails. In these tests four-inch lengths of 2¼ inch maple flooring were fastened with a single cut nail driven at a 50° angle into sections of a Southern yellow pine joist. A second grooved strip was then butted against the nailed tongue so that lateral loading could be applied to the nail from either direction. Loads were applied in a modified Tinius-Olsen shear tool at the rate of 0.015 inch per minute.

The resistance values obtained from these lateral loading tests tended to coincide with the skewed condition of the movement curves. Average lateral resistance in the direction of the 50° nail slope was found to be 384 pounds per nail, while lateral resistance in the opposite direction averaged 363 pounds. Further research in lateral nail resistance may indicate that a greater allowance for expansion is required at the floor edge between the first strip and the wall than the allowance required between the last strip and the wall.

Relationship of Tongue and Groove Design to Buckling

Buckling, a condition caused by excessive swelling of the flooring strips and subsequent loosening of the nails, was also investigated. Since tongue and groove design was thought to have a considerable effect upon the condition known as buckling, a series of compression tests were performed on small panels of flooring with conventional tongue and groove joints and on other panels having a modified tongue and groove design.

A study of the conventional tongue and groove disclosed the fact that, when laid on a flat surface, actual contact between a mated tongue and groove joint occurs only from the floor surface to a depth of approximately one-tenth inch. The upper illustration in Figure 4 shows the small area of actual contact. Since this point of contact is always at the floor surface, any swelling which takes place results in an accumulation of stresses in the upper portions of each strip which tend to produce an arch effect and force the strips away from the subfloor. When the resultant of these stresses exceeds the withdrawal resistance of the nails

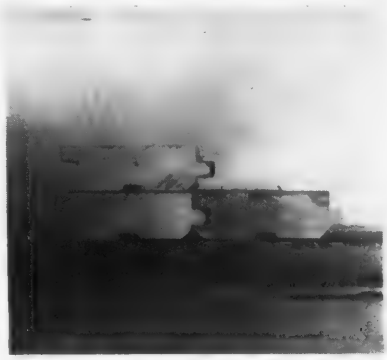

Figure 4.—Top: Modified joint designed to reduce buckling. Below: Conventional flooring joint showing the angle of contact above the tongue and the expansion gap at the bottom.

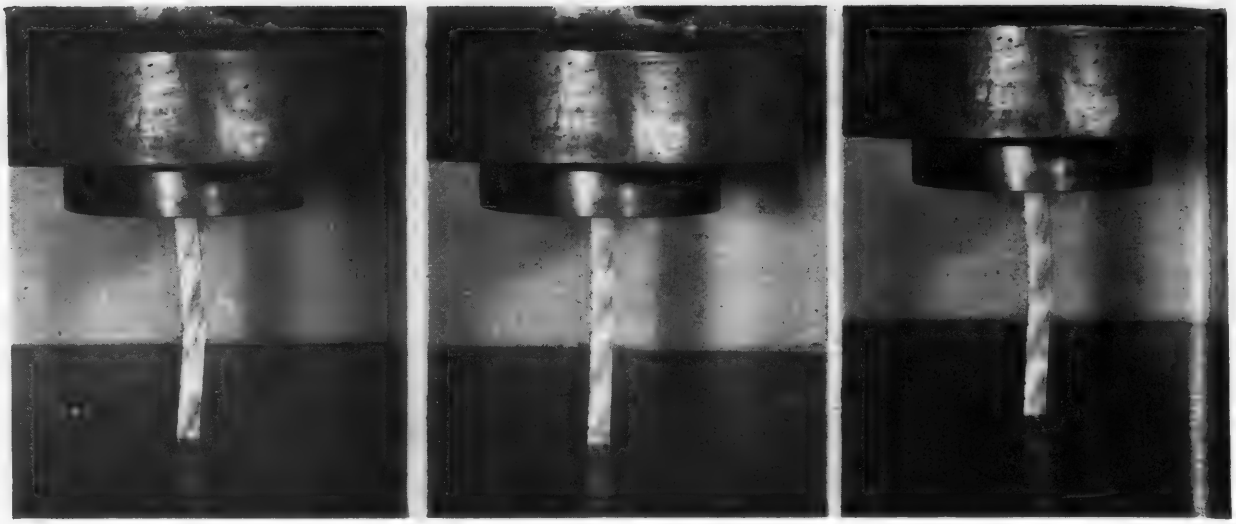

Figure 5.—Method of determining buckling resistance. Left: Conventional flooring about to buckle at 896 psi. Center: Flooring with modified tongue and groove loaded to 896 psi. Right: Same modified specimen with load increased to 1344 psi.

along any strip, a buckled condition occurs.

In an effort to increase resistance to buckling, a quantity of 2¼ inch flooring strips was modified by jointing the grooved edge to produce true vertical surfaces and intimate contact of the strips above and below the tongue. A series of compression tests were then performed on small panels having conventional and modified joints. These panels, consisting of three mated strips four inches in length, were placed on edge between rigid bearing heads. Loading was then applied at the rate of 0.015 inch per minute until buckling occurred.

Average buckling loads for the two types of tongue and groove joint show the modified joint to be definitely superior in resistance to buckling. The average stress required to buckle conventional flooring strips was 946 psi, while the modified flooring withstood an average stress of 1,396 psi before buckling occurred.

The three buckling specimens in Figure 5 further illustrate the superiority of the modified joint. At the left a specimen having conventional joints is about to buckle at 896 psi, in the center a modified panel shows no tendency to buckle under 896 psi, and at the right the same specimen shows only slight buckling at a load of 1,344 psi.

Throughout these tests all buckling failures occurred in the direction of the floor surface, even though extreme care was taken to joint the edge of the specimens which bore against the loading surfaces to perfect right angles. This condition, however, was probably caused by the fact that, even for the modified joints, the greater portion of the bearing surface occurs above the tongue.

Although results with the modified tongue and groove were promising, further investigations are being conducted to determine whether this type of joint will result in increased overall expansion because of the greater resistance to compression offered by the vertical bearing surfaces.

Expansion of Larger Floor Areas

One of the purposes of this investigation was to correlate the expansion of panels four feet in width with the expansion which might be expected for wider floors. A study of the movement curves in Figure 3, however, seemed to indicate that floors laid in the manner herein described, and at a moisture content approaching the average local equilibrium moisture content for interior wood, would not expand appreciably more than the four-foot sample panels. The previously mentioned movement curves may be used to explain the principle involved: taking any of the three curves and tracing from either side, flooring movement was noted to decrease as the center of the panel was approached, or as the restraining nails increased in number. For the narrow strip flooring, movement quickly decreased because of the closer nail spacing and the greater number of joints where minute compression failures could occur. For all three strip widths, however, a point was reached where the cumulative restraining force of the nails was sufficient to prevent further movement. The central portion of the panel then remained relatively stable.

On the basis of results obtained from the conditioning of various test panels and the analysis of the movement graphs, it was assumed that a carefully constructed maple floor, of any width, should show no greater expansion under high humidities than the test panels in this investigation. Examination of the expansion curves show this total expansion to be approximately 0.75 inch for 3¼ inch flooring, 0.65 inch for 2¼ inch flooring, and 0.30 inch for 1½ inch flooring, when 2¼ inch cut nails are used and joists are spaced 16 inches center to center.

The conclusions which may be drawn from this preliminary investigation may be summarized as follows: total flooring expansion for wide strips is greater than the expansion of floors laid with narrow strips; mastic appears to offer no advantage over heavy waterproofed building paper as a moisture barrier; a slight decrease in total expansion may be achieved by preboring all flooring strips before the nail is driven; nail resistance increases toward the center of a flooring installation and decreases near the edges; flooring nails offer greatest resistance to expansion in the direction of the nail slope; and conventional tongue and groove designs tend to cause accumulation of stresses which may result in buckling. This tendency can be considerably lessened by a slight modification in design.

In continuation of the program described herein ten additional expansion panels (4 ft. by 4 ft.) are being constructed and will also be subjected to high humidity. Variables under consideration in this portion of the investigation include the relative expansion retarding abilities of four types of flooring nails, a hot mastic and a wood stabilizer. In addition to these tests, several nailing techniques and the expansion of unnailed flooring laid in hot mastic will also be investigated.

The "Hot Spray" Process

GEORGE W. RHINE

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Hot spraying effects many advantages and economics over the cold spray application of paints and lacquers, particularly in the benefits accruing from reduced solvent requirements. Operation of hot spray apparatus is explained and advantages listed.

HOW DOES A TYPICAL "hot spray" apparatus work. Most readers are familiar with the principle governing ordinary spray painting: paint in a container is forced or drawn along various lines to the spray gun nozzle. Here it is ejected from the paint jet to become simultaneously mixed with an air blast that yields an atomized paint-spray cone. With hot spray the following innovations are introduced: it is sometimes customary to heat the paint while in the reservoir. This is variously accomplished by steam, hot water, hot air, or electricity. The paint is then forced or drawn along lines to the nozzle of the gun. Here the air blasts (sometimes consisting of warmed air) are mingled with the lowered viscosity paint to give an atomized cone of warm, denser bodied finish. Variations of the process include: heating only small amounts of finish immediately prior to ejection. This eliminates the danger of prolonged "over cooking" of large batches of paint. Some manufacturers prefer to use cold (room temperature) air for blasting in atomization rather than the warm air. Fundamentally, the merit of all the various methods is always practically demonstrated in the quality of resulting finish coats.

Let us examine the status of solvents as used in the "cold spray" method. To begin with the operator must have about twice as much solvent in his finish container as he would need with "hot spray". This means drastically diluted solid content. As one manufacturer has remarked, "The work of the thinner is all done by the time it has traveled one inch from the gun nozzle". Its sole purpose was to get the paint out of the gun and all it can do after being sprayed on the surface is to evaporate so the paint may dry. As the solvent is cold, temperature at the point of atomization (apex of spray cone) is not conducive to evaporation and much excess solvent continues right along with the finish to be laid down on the surface being prepared. Perhaps it might be an overstatement to say the "sole purpose of the thinner is to get the paint out of the gun". While substantially true, it should be noted that an optimum amount must go along with the solids to assure their proper distribution and flow, but that this has always been excessive in "cold spray" is what we wish to demonstrate.

Bearing these facts in mind, let us now consider the air pressures used during "cold spray" painting. Tests have shown that just about twice as much air pressure is needed to spray cold as hot. . . . Several corollaries follow from this. One immediate one is increased cost. It is decidedly more expensive to pump and maintain high air pressures. Another is loss of solids from increased fog. One of the first things noticeable with hot spray is the reduction in the amount of wasted solids that float away in clouds of expensive "paint fog". So great is reduction of this factor with "hot spray" that workers often dispense with masks and protective equipment. With "cold spray" pressures, technicians tell us that twenty five and fifty percent of all the material coming through the gun nozzle is lost.

Notice that the crucial roles of solvents and air pressures in spraying are under rigid control in "hot spray" methods.

So we see the "hot spray" process originally pioneered as a means of circumventing solvent deficiencies but with continued research eventually introducing whole new "philosophy" of finish application. Here are a few of the benefits obtainable through use of "hot spray" methods:

1) **Initial Saving** because "hot spray" reduces individual operations of sprayers, a great economizing of labor is realized. For instance, one pass with the gun is often all that is required. This eliminates former crisscrossing and back-stroking over painted areas. One coat is sufficient cover. Initial high deposit of solids means that once the article being finished is sprayed it is ready for packing and shipping; no standing around waiting for a second or third trip through the spray booth. Speeded-up drying cycles mean surface is ready for handling sooner. Production bottlenecks are eliminated and time-consuming drying periods are negated. "Hot spray" can in many cases eliminate the need for oven baking of enamels with attendant high investment and maintainance costs for oven equipment. Where baked enamel finishes are essential for the end product, use of "hot spray" with its lowered solvents ratio can often eliminate flash periods and in any case greatly reduce amount of flash time required. Less solvent is needed. Consumption of thinners is often reduced by fifty percent. Overspray is reduced. Properly controlled factors standardize the amount of finish needed; "guesswork" of individual spray operators is eliminated. There are fewer rejects. There is a drop in sanding and polishing requirements. Air consumption is halved. We find a true economizing note introduced to spray printing; a process whose former inherent wastage was tolerated only because it was a fast, clean method of finish application.
2) **Increased Production.** Uniform temperature control means attainment of increased output which usually follows standardizing of operation in production. The one coat aspect means faster delivery; less idle floor space needed for holding half-finished items.
3) **Increased Quality of Finish.** Greater depth of finish is obtainable. Lustre, beauty and "sales appeal" qualities are enhanced. Minute imperfections on surfaces are more easily covered because reduction of film shrinkage follows reduction in amount of solvent. Cold-check resistance is heightened. Blushing, orange peel and the host of "finishers'

ills" that attend variable atmospheric conditions are eliminated. With controlled temperature application the paint sprayer, like the scientist, sets his own conditions for operation and maintains them whether prevailing conditions are hot, dry, humid or cold.

4) **Greater Safety for Personnel.** Reduced spray fog, as mentioned previously, means greater pulmonary protection. Coupled with this is the lowered amount of dispersed solvent fumes liable to be inhaled. Completely explosion-proof and independently underwritten units eliminate fire and explosion hazards. With "hot spraying" production methods, lacquers and thinners may be stored outside of building, summer or winter. Controlled heat raises finish to exactly optimum conditions, therefore initial temperature of stored finishes is immaterial. "Hot spray" methods are even reflected in the lowered cost of heating plants in winter because less exhaustion of air to outside is required.

Surely this brief review of the beneficial results obtainable with "hot spray" should attract the far-seeing finish-production manager who seeks to improve operations.

Finishes successfully applied via "hot spray" methods include lacquers and enamels of the various organic and synthetic paint groups. While we are not going to enter the highly technical discussion of what formulations are best to use, it nevertheless is appropriate to point out a few highlights on the subject of finishes. Users often ask, "Can I use regular cold-formulated finishes in my "hot spray" apparatus?". No dogmatic answer to this is possible. Cold-formulated paints have been successfully applied with "hot spray" methods. In some cases they have even exceeded the requirement specified for cold applications. But speaking generally, it may be observed that use of cold-formulated paints in "hot spray" apparatuses is inviting trouble. Basically they are just not constituted for adaption. We have already reviewed the crucial role of solvents in this matter and now know that the high solvent ratio in cold paints would work against successful application in the long run. It is advisable to use the special hot-formulated finishes now obtainable through many sources. These are made with view to use in hot-sprayers and as such are manufactured accordingly.

We might note in passing one of the outstanding developments in paint formulations which has provided such a wide variety of finishes for "hot spray" application. This was introduction of nitrocellulose-based finishes. Because cellulose has inherently lower viscosity, it proved ideal for adaption in formulation of many "hot spray" finishes.

Applicability

All the foregoing finishes are equally applicable to metal or wood. Because we are concerned with the latter, we shall not enter discussion of the metal coating problem. Perhaps for wood there has never been a coating which exceeded in popularity the qualities of lacquer. Lacquer has many superior advantages to recommend it to wood finishing. Its one slight drawback in former days was the great amount of volatile solvent needed to cut it sufficiently for spray gun application. "Hot Spray" has conclusively removed this barrier. Tests show that pigmented lacquers are not degraded by "hot spray" methods. Wood finishers who fail to take advantage of this modern simplified method of lacquer application are needlessly siding with the past. We have mentioned previously how Europeans have been ahead of us in "hot spray" technique, at least as regards the war years. In Sweden alone, figures show that ninety percent of all lacquer applied there today is "hot sprayed".

To cite a few manufactured wood items that should be, and are, successfully "hot sprayed" we might note: Pianos, furniture (home and office), radio and television cabinets, caskets, picture frames, coffee tables, cedar chests, store fixtures, et al. Perhaps picking at random a few of the more successful applications of "hot sprayed" lacquer in the wood finishing industry at large will further illustrate the applicability of the process. A furniture manufacturer reports outstanding success with "hot spraying" of upholstered furniture even where the wood was porous and had considerable end grain. Here we note the advantage of denser solids content. A like manufacturer of gum-wood ranch furniture reported more durable finishes obtained with hotspray. A refinisher of pine and fir bleacher seats reported one application of "hot spray" replacing as many as three separate coats applied previously. A manufacturer of cedar chests tells of better light resistance and easier rubbing for hot lacquer. One application of high solids (no reducer) spray was found sufficient by one gun stock manufacturer to yield a standard uniform high-quality finish for his product. Hot lacquer was successfully sprayed over wiping stain by a picture frame moulder. Pine furniture finished with "hot spray" reportedly saved two coats and forty-six percent of the former labor cost. Rattan furniture, store fixtures, wood boxes—the list of wood and wood items finished by the "hot spray" process might be extended indefinitely, but the point is surely demonstrated. "Hot spray" is the finishing industry's newest aid towards increased production and high standard goods. It certainly deserves early investigation by those engaged in finish-coating of the nation's products.

COMPARATIVE STRENGTH OF AIR-DRIED AND KILN-DRIED WOOD

Some wood users claim that kiln-dried wood is brash and not equal in strength to wood that is air dried. Others advance figures purporting to show that kiln-dried wood is much stronger than air-dried wood. But some 150,000 comparative strength tests, made by the Forest Products Laboratory, of the U. S. Forest Service, on kiln-dried and air-dried specimens of 28 common species of wood show that good kiln drying and good air drying have the same effect upon the strength of the wood.

The belief that kiln drying produces stronger wood than air drying is usually the result of failure to consider differences in moisture content. The moisture content of wood on leaving the kiln is generally from 2 to 6 per cent lower than that of thoroughly air-dried wood. Since wood rapidly increases in strength with loss of moisture, higher strength values may be obtained temporarily from kiln-dried wood that has not come into equilibrium with the atmosphere than would be obtained from air-dried wood. Such a difference in strength has no real significance, however, since in use a piece of wood will come to practically the same moisture condition whether it is kiln dried or air dried.

It must be emphasized that the appearance of the dried wood is not a reliable criterion of the effect the drying process has had upon its strength. . . . from U. S. Forest Products Laboratory.

The Use of Toners in Furniture Finishing[1]

J. R. HOLLINGER

Lacquer Superintendent, Sherwin-Williams Co., Gibbsboro, N. J.

Toners in modern furniture finishing are used to change the color of wood while retaining its characteristics. Paper discusses advantages and disadvantages, and notes that toners are best used for their own special effects and not as an imitation of other finishes.

FOR MANY YEARS most of the furniture manufactured in this country was of period design and was finished with the familiar stain, filler and transparent finish coats. In recent years we have seen a steady and ever increasing tendency toward modern design and a radical departure from the older methods of obtaining color on wood furniture.

In the conventional type of furniture finish the color is achieved by use of dye stains, pigmented wiping stains, fillers, glazes and tinted sealers or top coats. Lack of opacity is the common property of materials of this kind. They are used to emphasize or accentuate the natural figure of the wood without completely hiding it. Naturally, there is an endless variety of colors that can be obtained by these methods but the effects are similar and vary only in degree and not in character. This type of finish possesses great beauty and will probably always retain a degree of popularity.

The modern finish so much in evidence today has departed from the old conception of preserving the basic color of the wood and attempts to produce a pleasing effect by radically changing its color while retaining its character. This is often accomplished by bleaching the wood and then proceeding with the finishing operation in the usual manner. The bleaching process makes possible the production of many striking color effects and is probably desirable from the designers viewpoint but is only a continuous headache for the production man. The difficulties inherent in the bleaching process are probably partially responsible for the increased use of other methods for obtaining unusual color effects.

Obviously the easiest way to change the color of anything is to hide it with a different color. Substantially this is what is done by the use of toners in modern furniture finishing. The word "toner" has many meanings in the paint business but for the purpose of this discussion we define a toner as a pigmented lacquer of good opacity and suitable for use under transparent furniture lacquers. When toners are applied at full hiding both the original color and the identity of the wood are completely lost and the piece appears to be merely painted. The pore and grain pattern is then restored by filling with a filler of contrasting color. By thus emphasizing the characteristic pore and grain pattern the wood loses its painted appearance and, except for color, again assumes the appearance one expects of a piece of furniture wood. In addition to the color derived from the filler, glazing or shading is usually used to complete the color effect.

Judging from the examination of a number of toners in use today there seems to be considerable disagreement concerning the qualities that are desirable in a product of this kind. Some of these products resemble a highly pigmented sanding surfacer while others are more like a lightly tinted clear lacquer. Neither of these fit our definition of a toner and in our opinion are not suitable for this type of finish. The former will have a tendency to fill the wood to too great an extent and might also promote cracking of the finish while the latter will not have sufficient capacity and will tend to produce more of a stained effect rather than the true toner effect.

The use of toners in furniture finishing can most easily be described by the following typical system for the production of a blond finish on red mahogany:

1. Spray a solid hiding coat of a toner of the proper color. Dry one hour.
2. Apply lacquer wash-coat. Dry 30 minutes. Sand.
3. Fill with regular wood filler of the desired color and allow the usual time for filler drying depending upon the type filler used.
4. Apply color-retention type lacquer sealer. Dry 30 minutes.
4. Sand sealer. Shade or glaze if desired.
6. Apply first finish coat of color-retention type lacquer. Dry.
7. Apply second finish coat of color-retention type lacquer. Dry.
8. Rub.

It is apparent that there is nothing unusual about the above system. The toner simply takes the place of the staining operation. In many conveyor finishing plants the toner coat can be applied at a stain booth although some additional time or heat may have to be provided for drying. The primary function of a toner is to change the color of the wood to which it is applied. Since it is a lacquer of good opacity the degree of color change achieved can vary anywhere from the natural color of the wood to the color of the toner, depending upon the thickness of film applied. The hiding power of a toner should be as great as possible consistent with good quality so that the desired color can be reached with the minimum film thickness. A thin film is desirable in order to prevent filling of the pores of the wood. In practice it will be found that it is easier to maintain uniformity if full hiding coats are applied.

A toner should have good color retention in both light and in darkness. One of the most difficult problems facing both the furniture manufacturer and the lacquer chemist is the maintenance of color of light finishes. Toners can be of some help with this problem because it is possible to make pigmented lacquers which have better fastness to light than most light-colored or bleached woods. Of course, careful attention must be given to the selection of sealers and topcoats so that the good color properties of the toner are not nullified by color changes in the finish coats. An example of this is the case of a warm blue-gray finish with white pores which has turned to a sickly green with yellow pores because of yellowing of the sealer and clear lacquer topcoats. Since toners can have good light fastness we have greater freedom in choosing suitable finishing lacquers than is the case with bleached wood. With light-colored or

(Continued on page 86)

[1] Presented at meeting of Forest Products Research Society, Northeast Section, December 4–5, 1952, at New York City.

Current Trends in Furniture Finishes[1]

GEORGE B. GIBSON
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Synthetic finishes are now finding a place in the furniture field to a degree that appears to constitute a trend. Their characteristics and advantages and disadvantages as compared to lacquers are discussed.

IN DISCUSSING "TRENDS" of any kind it is always of interest to examine the origin of the trend and perhaps to analyze the factors which led that "trend" to become a well established procedure or a generally accepted method after a period of usage and development. A "trend" is defined as a general course or direction in which an idea or a movement proceeds, but the survival of a movement depends entirely on its fundamental soundness and its contribution to the well being of society. When a trend develops and grows successfully, it ceases to be a trend and becomes standard practice.

To cite an outstanding example we need only consider the development of finishes based on low viscosity nitrocellulose, which have revolutionized the finishing processes for automobiles, furniture and general industrial articles. Because of the general all around soundness of nitrocellulose as a primary film former the progress in the development of finishes based on it was very rapid and at present, the technology of nitrocellulose formulations is perhaps the most highly developed. Obviously the most important factor which started the lacquer trend was the rapidity of the drying time which greatly accelerated the finishing time and consequently the finishing costs in the industry, particularly in the automotive and furniture fields. Apart from the drying time, the large complex molecule of nitrated cellulose, properly plasticized and modified with other resins had great outdoor durability, polishability and attractive appearance, and consequently, the lacquer usage passed from a trend into an epoch-making standard practice, which is still with us and will probably remain for some time.

Alkyd Resins Start Trend

The similarly spectacular, and to some extent parallel, success of alkyd resins has started another trend of thought in the formulation of finishing materials and, because of its fundamental soundness, has opened up a new and fruitful field for research, development and utilization.

With nitrocellulose, the nitrated molecule of cellulose is only partially a man made product; with alkyd resins and host of other synthetic materials which are now being developed at an ever expanding rate, the molecule is "made-to-order" and it is possible to modify this molecule chemically to build any desired set of properties into it.

Some very acceptable synthetic finishes for wood are now finding their place in the market and in this way constitute a definite trend. The origin of this trend is due first to the expanded knowledge of large molecule chemistry and second to the demands by the furniture manufacturers for finishing systems which will improve quality and diminish finishing costs.

Before going on to the description of synthetic materials it may be well to examine the attributes of a desirable film forming material, particularly as it affects furniture production finishing. These are as follows:

(1) Ease of application out of solutions at the highest possible total solids, and from as inexpensive a solvent combination as possible since the solvent is mainly a solids carrier and is lost by evaporation, thus being an economic waste.
(2) The finish must have the fastest possible drying rate consistent with good film formation such as good flow and levelling.
(3) Good color and color retention on aging, exposure to light and average home atmospheres.
(4) Greatest possible resistance to such physical forces as marring, scratching, abrasion, to chemical forces such as grease, alcohol, soap and to water resistance. In some cases resistance to lacquer solvents is also desirable.
(5) Cold check resistance, or low temperature flexibility.
(6) Good initial gloss and good processing properties.

It will be seen that the above properties if realized to the full extent in one finish would indeed produce a very superior finish.

Modern Lacquers

A well formulated modern lacquer comes remarkably close to fulfilling most of the above requirements, since, as was pointed out before, our lacquer technology is quite advanced and has taken advantage of very significant developments in the resin, plasticizer, and solvent fields. However, the large molecular size of even the lowest practical viscosity nitrocellulose does not permit formulation of finishes of high enough solids at the gun to give adequate build for processing in two or less coats. In addition, the solubility properties require the use of comparatively expensive solvents, whose sole function is to deposit a technologically acceptable film and whose (in most cases) unrecoverable evaporation represents an economic loss. It will readily be seen therefore, that, in the case of lacquers, the most important failing lies in item one of the properties outlined above. Some attempts to overcome this failing have resulted in the development of the hot spray technique which shall be discussed later.

Lacquer systems are externally plasticized systems, that is to say, the plasticizing additives are not in chemical combination with nitrocellulose and there is a tendency for lacquers to become progressively more brittle in the aging process. Elimination, of as much as possible of this, is feasible by a proper choice of plasticizers. A better solution is in the internal plasticization of a film forming molecule.

Synthetics

Synthetics can overcome the above weak points of a lacquer by the following:

(1) A synthetic film former may be made of a molecular size small enough to permit higher solids at the gun (40–60%). After application the molecular size is greatly increased either

[1] Presented at meeting of the Forest Products Research Society, Eastern Canadian Section, March 5–6, 1953, at Toronto, Ont.

by heat (baking) or under catalytic action (use of accelerators) or both. The smaller molecules combine with themselves, cross link and form a highly resistant film. Solvents required for synthetic materials are usually of the less expensive kind and because of the higher concentration of film forming material, less solvent is required, thus introducing a duofold saving to the user: (a) saving in application time (direct) and (b) saving in solvent (indirect).

(2) Synthetic film formers may be made as internally plasticized systems. By this, I mean that unlike nitrocellulose, plasticizing components are reacted right into the molecule and thus form part of that molecule. Alkyd resins modified with fatty acids may be cited as examples of such internally plasticized systems, but similar modification may be generally applied to many other film formers. The permanency of plasticization, and thus flexibility retention of systems of this type may be expected to be higher than with lacquers. Indeed the outstanding exterior durability of alkyd resin containing enamels is a direct proof of this.

A typically "normal" synthetic wood finish designed for low temperature baking, normally carries between 40–50% solids and is therefore about double the average lacquer solids. It may be sprayed at the above solids with equal or greater ease than the lacquer (with suitable spraying equipment), and will in most instances replace two coats of lacquer. The quality of the film is at least equal to lacquer with an advantage in alcohol resistance. The cure time of a synthetic of this type averages one hour at 140° F. Because at this bake the film is cured to its optimum properties, it is ready to rub and polish after cooling to room temperature. This "normal" synthetic finish will air dry in time to a satisfactory film but it is recommended that the bake indicated above be used to realize its optimum film properties quickly. The flow of the synthetic finishes is quite akin to that of the older oleoresinous varnishes and the tendency is to fill the pore rather than to form a pile around the pore edge as is often the case with lacquers. Baking ovens for furniture sprayed with the synthetics should have a relative humidity of 30–35% to prevent damage to glue joints and to minimize as much as possible any changes in the moisture content of the wood (which should normally be between 6–8% when the furniture is finished). Uneven distribution of moisture in the veneer often leads to "grain raising" and checking which are certain to spoil the appearance of any finish.

The pot life of normal synthetic wood finish is not a problem and the re-coat time, is short since after baking the film only needs to cool to room temperature before accepting the next coat. In this way, it may be recoated faster than lacquer since the lacquer should dry for at least four hours before re-coating in order to minimize shrinkage.

In addition to the "normal" synthetic finishes described above there is a trend towards "super" finishes which have exceptional mar-resistance, "toughness" and chemical resistance of the same order as that of "Formica".

Finishes of this type are similar in solids and application properties to the one described above. However, as a general rule, the catalyst or "accelerator" which is used with the type is added just prior to the application of the finish and the pot life is short because of the great reactivity of this finish. Usually, the pot life is long enough to allow for a full day's production. The properties that may be obtained with finishes of "super" type are so attractive and so superior to any that were offered before, that it is possible they will find a place of their own not only in the furniture finishing field but also for such uses as gymnasium and bowling alley floors, school furniture, sports equipment, and generally, wood articles requiring outstanding toughness.

"Super" synthetic finishes reach their optimum properties after a one hour bake at 140° F. but will also cure at ordinary room temperatures in 16 hours to a stage at which they may be rubbed and polished. An article finished in the foregoing manner may be handled about ½–1 hour after spraying which puts it in the same class as a lacquer with respect to this property.

In the following table the properties of lacquers and synthetics are compared. This is done by assigning a value of 10 to the highest evaluation of an individual property. Valuation at about 5 indicates a passable property, while values below 5 represent an unsatisfactory rating for that property.

It must be emphasized that the values shown in the table are arbitrary and are to some extent based on the evaluator's opinion.

Hot Spray Lacquers

There is a definite trend now to get the maximum solids at the gun with nitrocellulose lacquers by employing the hot spray technique. This technique utilizes the simple principle that the viscosity is lowered as the temperature is increased. With lacquers, such lowering of viscosity is appreciable and

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TABLE I

COMPARISON OF LACQUER vs. SYNTHETICS

Property	Good Quality Modern Lacquer	"Normal" Type Synthetic	"Super" Type Synthetic
Toughness - work required to break the film	7 1/2	8	10
Mar resistance	8	9	10
Adhesion to wood	8	9	10
Ease of polishing	10	8	8
Sandability	7	7	10
Alcohol resistance	5	8	10
Lacquer solvent resistance	0	5	10
Water resistance	10	8	7
Print resistance	8	10	10
Cold check resistance	10	10	10
Initial gloss	8	9	8
Rubbed gloss	10	8	8
Color retention	9	9	9

Alkyd Resin Characteristics Applicable to Wood Finishes[1]

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Based on research and experience, alkyd resins can now be produced from a combination of ingredients and processing schedule to meet a wide range of finishing requirements.

IN CHEMICAL TERMINOLOGY an alkyd resin may be described as a combination of a polybasic acid with a polyhydric alcohol. Specifically, polybasic acids include phthalic and maleic anhydrides, fumaric acid, etc., and polyhydric alcohols include the various glycols, glycerin and pentaerithrytol. Generally alkyd resins are modified with oils, oil fatty acids and other similar materials. The usual type of alkyd resin consists of phthalic anhydride, glycerin and oil fatty acids, which have excellent characteristics, and in normal times are available in large volume. Phthalic anhydride especially is definitely superior to the other polybasic acids in making resins with excellent outdoor durability. With these components a wide range of resins may be made by varying the proportions of the ingredients, the type of oils and the processing conditions. Backed by many years of laboratory research and the experience gained from diversified industrial uses, the resin manufacturers can select, fairly arcurately, the combination of ingredients and processing schedule which will yield a resin having the desired physical properties and performance characteristics.

Alkyd resins in which the glycols are used are normally non-drying or extremely slow drying resins. Glycerin produces resins with good drying characteristics and with excellent durability. The pentaerithrytols yield resins with extremely fast drying properties; however, there is a tendency to embrittlement on aging which may detract somewhat from their exterior durability properties.

In general, oil-modified alkyd resins take on the characteristics and properties of the modifying oil. For example: linseed oil modified resins have excellent drying properties, while resins made with coconut and castor oil are non-drying. Similarly, resins modified with linseed oil usually have much better outdoor durability and faster drying rates than those made with soya bean oil. However, soya bean oil modified resins have much better color retention than do linseed oil resins.

Modification with rosin tends to decrease the outdoor durability of an alkyd resin, although the initial gloss is frequently increased. Phenol modification tends to improve water resistance but gives much poorer color and color retention.

During the past few years almost all resin manufacturers have introduced co-polymer type resins, which are essentially oil modified alkyds further modified with a monomeric material, such as styrene, and processed to a state of polymerization which yields satisfactory resin properties. These resins are characterized by extremely fast drying properties, improved alkali resistance, and exceptional color retention; they are, however, lacking in resistance to solvents and resistance to surface marring. The durability characteristics of these so-called copolymer resins are generally comparable to those of oil modified alkyds of similar oil length.

Alkyd resins have many desirable characteristics which are utilized in finishes for wood surfaces for both protection and decoration. Among these are durability beyond that of other surface coatings, fast and positive drying rates, excellent intial color and gloss and the ability to preserve these important factors over long periods of service. They possess sufficient resistance to water, chemicals and solvents for normal conditions and exposures.

Exterior Uses

On exterior lumber surfaces, alkyd type resins may be used as the vehicle for primer coats, trim paints, and clear sealer coats. Non-penetrating type resins can be formulated into exterior primer coats to supply bridging over surface grains and minor surface defects, giving a surface of good uniformity. The excellent color retention and gloss retention of alkyd resins indicate their use in trim paints, especially where strong colors are to be used. Since paints of this type are normally low in pigmentation, the alkyd resin may be used as the complete vehicle without incurring too much difficulty in brushing. Additions of alkyd resins in the proportions of one-third to three-fourths of the total vehicle solids in oil type trim paints will fortify or up-grade them.

Interior enamels and undercoats demand fast drying finishes with excellent color and gloss retention. For these applications the alkyd type resin has predominated for many years since they do provide the ultimate in fast drying and appearance retention.

Alkyd type plasticizers used with nitrocellulose furniture lacquers give improved cold check resistance, which means that the life of a furniture finish is materially increased. They also provide films of excellent clarity and depth enhancing the natural beauty of wooden surfaces. The tendency of alkyd resins to maintain color throughout their long life results in finishes which maintain their original lustre and clarity over long periods of time. Alkyd resins also may be used in combination with amine-formaldehyde resins, which may be dried by catalyzation to produce films of similar hardness to baked films. These films also have excellent resistance to chemicals such as alcohol and greases, but they do suffer more from cold checking than well formulated lacquers.

Alkyd resins have been used on plywood as clear sealers to reduce the tendency towards face checking, thereby materially increasing the durability of finishes applied over them.

The application of alkyds to plywood as sealers can be done either by pressure impregnation or by simple dipping or brushing. Pressure impregnation is more expensive but has proved definitely more efficient than other methods of resin application in controlling checking and preparing the surface for subsequent paint coats.

One particular use of alkyds on plywood has been in Federal specification work, as in Ordnance Specification

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[1] Presented at meeting of Forest Products Research Society, Pacific Northwest Section, May 20, 1952, at Portland, Ore.

The Effect of Incising on the Binding Strength of Crossarms[1]

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The subject of the effect of incising on crossarm strength is not, perhaps, of broad interest in the forest products field. However, the simplified experimental design and analysis outlined in this paper is applicable to the entire field of research. The statistical test described herein is relatively new and is extremely useful. Those without a background in statistical techniques will find the test surprisingly easy to use.

Material Used

FORTY CROSSARMS were tested in this experiment.[2] Twenty six-foot, six-pin arms were used (pairs 1 to 10) as well as twenty six-foot, four-pin arms (pairs 11 to 20). The crossarms were cut from essentially clear, straight-grained material which ranged in specific gravity (oven dry volume basis) from 0.41 to 0.73. The material was kiln dried to a moisture content which ranged from 12 to 16 percent prior to surfacing to net dimensions of 3.20 inches by 4.20 inches. The six-pin arms were bored with holes 1.26 inches in diameter, whereas the four-pin arms had 1.50-inch holes.

The crossarm material used in these tests was originally twelve feet in length. Each piece was cut in half and the two halves were assigned the same number in order to designate matched pairs. One crossarm of each of the matched pairs was incised; the other arm was not incised. Due to the close matching little or no variation existed in either the specific gravity or the moisture content of the matched halves.

Incisions were made by an incising machine which used teeth of the "oyster-knife" type. The incisions—i.e., slits—were arranged in lengthwise rows and were spaced ½ to ⅜ inches apart in the row. Alternate rows were ⅜ of an inch apart and were staggered. The depth of penetration of the teeth was approximately $\frac{3}{16}$ inches.

Method of Testing

Static bending tests were made on a 30,000 lb. Olsen testing machine. A six-inch steel I-beam provided an extension bed for the testing machine. Upon this I-beam were placed two knife-edge rocker supports. Steel plates placed on the knife edges prevented local crushing of the wood.

Third point loading was used for the six-pin crossarms. A span length of 60 inches was used with a load spacing of 20 inches. The load was applied to a central knife edge and was distributed evenly through a four-inch I-beam to two rocking knife edges which were located at the desired loading points. Again, ¼-inch steel plates were used to prevent local crushing perpendicular to the grain. For the four-pin crossarms, a span of 68 inches was used in order to place the supports under the outer pin hole, and a 38-inch load spacing placed the loads over the inner pin hole. All crossarms were tested with the pin holes vertical. Pins were not placed in the holes.

The head speed of the machine was held constant throughout the tests. A speed of approximately 0.15 inches per minute was used for both types of arms. This speed was approximated from the standard formula for rate of fiber strain in third point loading.

Deflection readings were taken from an Ames dial which was connected to a small nail at the neutral plane in the center of the crossarm by means of a fine wire. Readings were taken to the nearest 0.001 inches at intervals of either 400 or 500 lbs. during the progress of the test. The testing machine was balanced for the weight of the equipment plus that of the crossarm, and a load of 75 to 100 lbs. was placed on the arm before the first deflection reading was taken.

The order of failure was noted on the crossarms if failure was unusual in any respect. Invariably failure occurred at one or both of the inner pin holes. Except where slight grain distortions were present on the tension side of the arms near the critical section, the order of failure was compression followed by tension. No shearing failures occurred.

The modulus of rupture was computed for each crossarm from the general flexure equation. The net breadth of the critical section was used in this calculation, since no factor had been determined for that which would allow for the effect of stress concentration about the pin hole.

After each test a moisture content specimen was cut near the point of failure. The mositure content specimens were also used to estimate the specific gravity, the number of rings per inch, and the percent summerwood. Moisture content was determined in the usual manner, i.e., by the oven drying method. After weighing the specimens in the oven dry condition (constant weight after drying at 215° F.) they were dipped in hot paraffin and the volume was determined by water displacement for the specific gravity calculation. The oven dry weight and the volume when oven dry were used in this computation.

Results of Tests

The accompanying table shows the test results. The values are paired for the easy comparison of the matched incised and unincised arms. It should be noted that four pairs of arms out of the original 20 are omitted. In these cases one of the crossarms of the pair failed at an abnormally low load which could be ascribed to a visible defect not present in the other specimen of the pair. In three of the four pairs omitted from comparison, low strength was caused by the influence of a knot on the lower surface which produced early tension failure.

The results show that in many—but not all—of the pairs the unincised arms carried greater loads and, concomittantly, greater stresses. If there were no difference in the strength of matched incised and unincised crossarms, one still would not expect an equal number of plus and minus differences within pairs due to human

[1] Presented at meeting of Forest Products Research Society, Pacific Northwest Section, February 3, 1953, at Tacoma, Wash.

[2] Material was supplied by the Oregon Crossarm Company of Portland, Oregon.

error and mechanical errors in testing as well as due to the cumulative effect of slight variations in moisture content, specific gravity, and other more subtle forms of natural variation in the wood itself, particularly at the outer surfaces of the specimen. The problem then is: Are the majority of values in favor of unincised arms due to a real difference in strength which reflects the effect of incising, or is this apparent difference the result of chance variation of the data due to the chance cumulation of natural, mechanical and human error? This question can only be answered by the statistical analysis of these data.

The Analysis of the Results

Experiments of the type which involved paired data are well suited to statistical analysis by means of the "sign" test.[3] This test is applicable to data where the total number of pairs are subdivided into several groups of data which are from different parts of an experiment. In this case the results of tests from the two types of arms can be handled as one set of data. The case of application of the sign test offers an additional advantage over the more familiar "t" test.[4]

The problem here is to determine whether or not incising lowers the bending strength of crossarms when compared to matched unincised arms. Recognizing the presence of slight variations of factors within pairs which effect the inherent strength of wood, we would expect the modulus of rupture values for unincised arms to be slightly greater than those of the incised arms only about 50 percent of the time if there were no difference due to incising. On the other hand if the unincised arms were stronger than the incised arms in every case we would know for certain that incising decreased the strength of the crossarms. What can we conclude when, out of 16 pairs of arms, the incised arms were stronger than the unincised in 4 cases? (See table). What chance have we of being correct when we tend to say that unincised arms are stronger?

The sign test enables us to predict the probability with which we might be wrong in our assertion about the superior strength of untreated arms. Using the reference cited (3) we refer to the table of critical value of "r" for the sign test. The number of paired arms for comparison being 16, we find this row in the "n" column. Next, using an "r" equal to 4 (the minority sign) we find that this value is in the 10 percent significance column or that our chance of being wrong in our assertion is 10%. In other words, there is only a 1 in 10 chance that there is no difference in the strength of matched unincised versus incised crossarms, or we have a 90% change of being correct in our assertion. This is an acceptable level of significance.

If there had been 5 minus signs in the comparisons our probability of being correct in assuming that untreated arms are stronger would have been only about 75%. This is considered an unacceptable level of significance. In other words, we would not be safe in making the same assumption.

Discussion

The literature reveals that incising Douglas fir railroad ties lowered the average bending strength only slightly more than two percent.[5] Incising was found to have caused a reduction of between 10 and 20 percent in the bending strength of laminated Douglas fir beams,[6] but the incisions were 5/8 inches long, 1/8 inch wide at the surface and 5/8 inches deep. It was pointed out in this test of twelve incised beams that the reduction in strength varied with the thickness of the stock and it probably would be a function of the beam size, type of knives and the incising pattern employed.

It would seem likely that the type of test performed in the experiment described in this report would be sensitive with respect to the effect of incising. A relatively large proportion of wood is incised in the area of the critical section. Compared to the reduction in strength due to minor defects, particularly on the tension side near the critical section, a four percent loss of bending strength—or even a larger loss—is incidental. The most important observation one can make from the data, however, is that the variation in the strengths between unpaired crossarms is far greater, percentagewise, than the loss of strength

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[3] Dixon & Massey, "Introduction to Statistical Analysis", McGraw-Hill, New York, 1951, pg. 247 et seq.

[4] Brownlee, "Industrial Experimentation", Chemical Publishing Co., New York, 1949, pgs. 32 & 33.

[5] R. H. Rawson, "A study of creosote treatment of six-inch by twelve-inch Douglas fir beams, covering boiling-under-vacuum-pressure process and the influence of incising" Proc. Am. Wood Preservers' Association, Chicago, 1927, pp. 203-13.

[6] O. Harry Schrader, Jr., "Tests on creosoted laminated stringers," **Engineering News** Record, November 15, 1945.

A STATISTICAL TEST OF THE SIGNIFICANCE OF THE DIFFERENCE, BY THE "SIGN TEST", BETWEEN MODULI OF RUPTURE FOR INCISED VERSUS UNINCISED CROSSARMS

(Paired data)

Crossarm Pair No.	Unincised	Incised	U-I
1	14,000 p.s.i.	14,500 p.s.i.	-
2	12,100	10,900	+
4	11,800	10,100	+
5	12,400	11,300	+
6	7,400	6,600	+
7	12,100	11,500	+
8	10,700	10,100	+
10	11,200	10,600	+
11	12,900	13,700	-
13	8,600	10,000	-
14	11,400	10,400	+
15	11,300	12,200	-
16	9,700	8,900	+
17	12,400	10,800	+
18	11,500	11,400	+
19	9,000	8,100	+
	178,500	171,100	
Average	11,150 p.s.i.	10,694 p.s.i.	

r=4 (total of minority sign)

N=16 total number of pairs (Note: 4 of the original 20 were omitted).

Probability (p) in favor of the unincised arms = 90%
Table 10, Dixon & Massey, shows 10% for (1-p).

Conclusion: Incised crossarms are significantly weaker than matched unincised arms in modulus of rupture.

Sizing Forest Products with Petrolatum[1]

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Petrolatum is now being used successfully as a sizing for wood fiber board products. It is effective with both wet and dry processes and has some specific advantages over other sizing methods. In certain phases of fiber board manufacture 10 to 20 percent less power is required due to lubricating effect of the hot petrolatum in the fiber mass.

THE TERM "SIZING" is a general term which expresses the use of a material to retard penetration of liquids into wood fiber or pulp products. For the present, it will be used only with respect to retarding water absorption. The improvement of sizing has been and continues to be an important problem of the industries using wood as a raw material.

In the hardboard industry, emulsions of paraffin wax or rosin are customarily used for sizing. A study was made to determine whether sizing could be accomplished without the expense of emulsifying the sizing agent. The sizing material used in this study was petrolatum derived from a waxy California crude oil.

Petrolatum is a complex mixture of high melting hydrocarbons and oil obtained from a high boiling, waxy petroleum fraction. It has a solid point well above room temperature and exists in very small crystals when solid. The oil content of petrolatum is usually between 15% and 30%, but this oil is occluded in the crystal structure and will not separate or bleed from the petrolatum. At room temperature, a petrolatum is normally pliable and tacky.

Wet Process Hardboard

The use of molten petrolatum for sizing hardboard made by the wet process was studied on a plant scale with gratifying results. Adequate sizing was obtained using approximately 1% petrolatum. Optimum sizing resulted when the fiber slurry was maintained slightly acid at a pH of 4.5 to 5.5 by the addition of alum, customarily used when sizing with a wax emulsion. Commercial use for extended periods of time has established the fact that sizing by this means is as effective as an emulsion size when the two types of sizing materials are on a dry weight basis.

[1] Presented at meeting of Forest Products Research Society, Pacific Northwest Section, February 1953, at Tacoma, Wash.

Semidry Process Hardboard

Molten petrolatum was found satisfactory in sizing hardboard made by the semidry process, where adequate sizing was obtained with 1% to 2% petrolatum. With certain species of wood, alum is not required; but with others, alum is essential to satisfactory sizing. In general, the relationship between board strength and petrolatum concentration is the same as for the wet process.

Dry Process Hardboard

In sizing hardboard made by the dry process, the problem of applying the sizing material is somewhat different from those presented in the wet and semidry processes. A spray application of molten petrolatum, which gave an even distribution of finely divided particles on the dry pulp, resulted in a board with sizing and strength well within manufacturing specifications. The use of liquid petrolatum for sizing eliminates the need for introducing additional moisture into the wood fibers, which is an objectionable feature of emulsion sizing in the dry process. This is an important advantage in the dry process because excessive moisture is detrimental and may be the controlling factor in making a satisfactory product.

Major Considerations

The primary problem in sizing wood fibers is adequate distribution of the sizing agent. Emulsions can be uniformly mixed with the fibers and precipitated upon them. When using petrolatum which is not emulsified, thorough mechanical mixing is required at a temperature above the melting point of the petrolatum. The absorption of the petrolatum on the fibers is improved by increasing the temperature, the time of storage at the elevated temperature, and the degree of mchanical action. The water content of the fibers should be maintained below the fiber saturation point. After the petrolatum is absorbed on the fibers, it is not displaced by water in further processing.

The experimental evidence accumulated from numerous plant tests shows that the theories used to explain the mechanism of sizing with an emulsion do not fit the experimental evidence when using petrolatum. According to one widely accepted theory, the emulsion sizing operation takes place in two steps: (1) the conversion of the alum to positively charged colloidal alumina particles, which are attracted to the relatively electronegative fibers making them electropositive; (2) attraction and deposition of the negatively charged wax or rosin particles on the fibers. Petrolatum in the liquid or solid form has no dipole properties nor does it ionize. It attaches itself firmly to the fibers without an assisting agent such as alum.

Strength Considerations

When using wax emulsions, it is commonly observed that hardboard strength decreases as the amount of emulsion in the board increases. Experimental evidence hows that this phenomenon does not occur with petrolatum. Within the range of practical consideration, hardboard strength is independent of petrolatum concentration. This indicates that the emulsifier has a significant bearing on board strength. It is interesting to note that the same conclusion was expressed informally by an independent investigator at a recent TAPPI meeting.

When petrolatum is added to the fiber before adding a resin, one might expect the petrolatum film to reduce the bonding properties of the resin. There was no evidence of this in any of the commercial tests.

Painting Characteristics

The painting characteristics of hardboard are of prime importance in many uses. Certain difficulties in painting hardboard are inherent with the product itself, but the type of sizing used can influence the paintability. The petrolatum used in this work has little or no effect on the drying characteristics of a paint film. In contrast, paraffin wax sizes retard the drying time of a paint coat, resulting in a soft film

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Timber in Modern Construction[1]

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Modern improvements in grading for use, joint designs and laminating are reclaiming for wood an enlarging part of the construction market. Today's connectors make it possible to develop maximum strength values in solid timber construction while glued laminated practices make it possible to develop desired architectural shapes. Laminating practices are discussed in some detail.

WOOD IS ONE of the oldest construction materials known to man, and has served faithfully and well for literally thousands of years; first as logs, later as hewn timbers and still more recently as beams, planks and posts sawn from logs by hand or by mills. Today it continues to rank as one of the most important of construction materials.

In the early days of western development timber was found to be plentiful and was widely used. As the western world grew in strength and population, so did it grow in numbers of skilled craftmen who hewed and squared up timbers and fitted them into place with precision. But with the perfection of Portland cement and the development of the steel industry, timber was assigned a place of less importance by the designers of the day. Precise methods of structural design were developed and applied to riveted steel structures and reinforced concrete. Wood could not be molded into desirable shapes; steel and concrete members could be connected more easily than wood, and appeared to be "permanent" materials. Skilled artisans in timber were gradually replaced by the riveter, the welder, and the concrete worker.

However wood was not forgotten as an excellent structural material; in recent decades many new developments have vastly enlarged the horizon of wood. Timber connectors such as split rings, shear plates, toothed rings, grids and many others have made connection simpler and more efficient. Lengthy studies by laboratories, scientific bodies and private enterprise have brought forth greater knowledge of the strength and physical properties of timber, permitting precision in design and resultant economy in its use. From this research, glued-laminated timber, ("glulam") has emerged as a new structural material having more desirable properties than timbers sawn from trees and making possible members whose size and shape have heretofore been obtainable only in other structural materials. These developments have returned timber to its rightful place among the materials available to the construction industry.

[1] Presented at meeting of the Forest Products Research Society, Eastern Canadian Section, March 5–6, 1953, at Toronto, Ont.

Timber as a Construction Medium

The field of timber construction may be divided into two major branches: the use of structures whose main components are timbers sawn naturally from logs and the use of those whose main components are synthesized by the process of glued-lamination from smaller boards or planks. Glulam has found great acceptance in Canada and the United States during and since World War II and previous to this had a long and successful record in Europe.

Of the species of timber available for structural use in Canada, Douglas Fir is one of the most plentiful and generally the most practical for both glulam and sawn structures. A little more expensive in the east than the eastern woods, its strength advantage usually outweighs its price disadvantage, and the resultant structural member is lower in cost than the equivalent structural member of an eastern species. Western hemlock is also used to some extent in glulam, as is white oak or treated red oak in marine applications.

Essential Functions of a Structural System

It can be said of any structural system that it must perform three essential functions in order to qualify as a satisfactory construction medium. First, it must perform a structural function, acting as the primary strength producing frame necessary to support the roof, the highway, or for some other utilitarian purpose.

Second, this structural system must also perform an *architectural function* lending itself readily to the desired shape and size of structure, and simultaneously to the use for which the structure is designed. In addition, its appearance must be in harmony with the nature of the structure, and its permanence must be assured under the conditions of service to which it will be subjected.

Third, and certainly not least, the material must perform an *economic function*. To say that it must be the cheapest of all available materials is short-sighted; rather, it must prove most economical in the long run. Often materials which have a low first cost have a high annual cost over a long period of service, as reflected in cost of maintenance, insurance, and additional work which must be done for the sake of appearance. Economic comparisons must always take into account all factors in the annual cost of the entire structure.

Like other construction materials, timber, either sawn or glulam, is not the universal answer to a builder's dream of a material which will best fulfill all requirements. However, timber has a good record of doing these basic jobs well, and it can be safely said that for many kinds of construction timber is unquestionably the best material.

Structural Characteristics of Wood

Wood has certain inherent characteristics which must be considered in comparing it with other structural

Laminated arches on 58 foot span are over 90 feet high at ridge. Purlins are also laminated. Organ grille is constructed of spruce scarfed and glued to form 50 foot lengths.

Modern wood-fabricated bridge. Three-leaf glued laminated top chords, sawn bottom chord, web members and flooring beams. All parts except hand railings pressure creosoted. Span is 70 feet, with 20-foot roadway. H-20 loading.

Details of laminated floor construction designed to carry storage loads. Photos by Timber Structures, Inc.

materials. Although for equal weight wood is stronger than steel, and for equal strength wood is lighter than steel, timber beams take up more space than steel beams designed to take the same load. Glued-laminated beams are stronger than sawn beams and thus take up less space; however, the additional depth which is required for beams or other structural timber members, must be considered in planning and designing.

It cannot be denied that wood is a combustible material, but it is surprisingly fire-retardant as well. Insurance underwriters give heavy timber construction a better rating than unprotected steel, and heavy timber or "mill-type" construction is usually considered to have about one-hour fire resistance. The slow-burning qualities of Douglas fir, about one inch in 33 minutes, coupled with the excellent heat-insulating properties of wood, are factors which contribute to fire resistance. The rectangular cross-section of conventional timber members presents a smaller exposed surface to fire and high temperatures in relation to the volume of material enclosed than do the rolled steel shapes. This is a contributing factor to the fire-resistance properties of wood.

The stiffness of wood as measured by its modulus of elasticity is less than one-tenth that of steel and only about one-fifth that of aluminum. For ordinary structural uses, however, stiffness is seldom a controlling factor, and a maximum allowable deflection controls the required size of timber beams in only a small number of cases.

Types of Sawn Timber Construction

In structural units whose primary members are of sawn timber careful consideration must be given in design to methods of making connections. In addition, some of the inherent characteristics of timber must be taken into account. Consideration of these factors has led to the use of the bowstring truss as the most efficient type of timber truss construction. Trusses of this shape approximate an ideal arch, in which the chord members are in almost pure compression and tension, and whose web members serve only to take care of unbalanced loadings, wind forces, variations in the method of loading and the shape of the truss. The circular shape of the bowstring truss is close enough to an ideal parabolic arch so as to cause almost negligible web stresses.

Bowstring trusses of multi-leaf segmented chord construction, known generally as Arch-Teco trusses, and monochord bowstring trusses having large solid sawn segments butted against each other to form the top chord, have become quite common in industrial building construction and are the most economical form of timber truss. The shape of the truss lends itself well to wide clear spans without excessive centre height, and the wind forces on the truss itself are very small.

Triangular and parallel chord trusses of similar construction can be built, either in multi-leaf or monochord design. In the larger parallel chord trusses of multi-leaf design, the web stresses become very large near the ends and the necessary number of connectors makes the joints unwieldy. Furthermore, whenever groups of connectors are to be placed between sawn members whose grains run at an angle to one another, possible drying with its consequent shrinkage between the time of fabrication and the time of aassembly must be considered. In such cases, the unequal shrinkage across grain often makes it difficult to assemble the joints. If they are assembled successfully the connector grooves may be forced out of shape and they are then unable to carry their design loads properly. An allowance for this is made in some design specifications, but it is generally considered best practice to steer clear of multi-connector joints if unseasoned or partially seasoned members are to be assembled along nonparalleled axes. When members are abutted as in the Arch-Teco truss, or where only one set of connectors on a single bolt is used in a joint, this difficulty does not exist. Of course if members are seasoned to equilibrium moisture content before fabrication this would not be a problem, but usually such seasoning of large timbers is impractical and unduly expensive.

Lightly loaded parallel chord or triangular truss or trussed rafter designs may be made in multi-leaf sawn construction, but are usually uneconomical of lumber since the size of the member is often controlled by the connector groups required. For the more heavily loaded trusses, rod and timber arrangements utilizing steel rod tension verticals and timber compression diagonals dapped into the chords have been found to be the most satisfactory.

Such parallel chord trusses, however, cannot compare in economy with the more nearly ideal bowstring truss. For this reason, many flattopped roofs have been built using bowstring truss construction for the main load carrying members, with sections built up to provide a flat roof, or to provide a raised peak for multi-span construction. Other structures, such as bridges, are designed by the same general methods, utilizing the bowstring principle whenever possible.

Design of Sawn Timber Structures

Much investigation as to proper design loads, stresses and connector

values has been made by research bodies in Canada and the United States, and all this material is summarized in excellent form in the National Design Specification, published by the National Lumber Manufacturers' Association of Washington, D. C. Working loads for all types of connecting hardware are given in this publication, and values for split-ring and shear plate timber connectors are also very well presented in the Manual of Timber Connector Design published by the Timber Engineering Co. of Washington, D. C. These two books are valuable working tools of the timber designer and are essential requirements for his library.

Although the National Design Specification is an American publication and refers to American lumber grades and standards, the working stress values given in it are similar to those set forth by Canadian Standard Association Specification 043, (1953, C.S.A. Specification for Structural Timber. This specification includes, of course, only timber grading rules and the design methods and working stresses associated with it; a combination of this C.S.A. Specification and the general requirements of the National Design Specification with regard to connections makes an excellent working combination. It is to be hoped that the new National Building Code of Canada will gather much of this excellent material under one set of covers and thus provide the timber designer with a compact, authoritative working tool.

Sawn Timber Versus Glulam

Sawn timber, of course, has its limitations. These must be considered in designing any timber structure. Of great importance is shape; sawn timbers are limited to long rectangular prisms or those curved shapes which can be conveniently band-sawed out of them. It is of course possible to steam and bend sawn timbers, but this is impractical for large timbers such as are usually encountered in construction.

Size is also a limiting factor in sawn timber design. Although it is still possible to obtain large timbers of great length from British Columbia mills, the problems of shipment and slow delivery, generally make their use impractical. Structural grade lengths over about 26′, command a premium price and usually require longer time for delivery.

Another inherent limitation of sawn timbers as structural components is their dimensional instability. It is impractical from a cost and time standpoint to allow all timbers to season to the equilibrium moisture content they will attain in service before they are fabricated and used. Practical considerations require that they be fabricated in an unseasoned or partially seasoned state. This means that some maintenance of interior structures must be carried out after a period of service; bolts must be tightened, and in detailing, allowance for shrinkage must be made when positioning joists and purlins.

The outstanding advantage of sawn timber as opposed to glued-laminated timber is its cost. Generally speaking, structural components made from sawn timbers are lower in first cost than those made from glued-laminated timbers, although their ultimate cost may be greater than glued timbers because of assembly costs, maintenance, and the frequent necessity of coverings for appearance reasons. Glulam solves many of the inherent difficulties of sawn timber construction.

Types of Glulam Construction

Glued-laminated timber, or glulam, is defined as the product obtained by gluing together relatively thin laminations having their grain essentially parallel. In this respect it differs from plywood, where the grain of adjacent plies lies at right angles. It differs also in strength, having the same orthotropic strength characteristics as sawn timbers. It is a more homogeneous material than sawn timber, however, because of the restriction and dispersion of the natural strength-controlling characteristics of individual laminations. Thus it is more dependable in use than sawn timbers, in which a single defect may control the value of an entire piece.

The development of the various types of glulam construction has followed along the same general lines as sawn construction, but with many variations and simplifications permitted by the flexibility of structural glulam. Glulam bowstring trusses are most economical and may be built with multi-leaf chords similar to the Arch-Teco, or with continuous single-leaf monochord design, spliced only where required for convenience of manufacture and shipping. Such construction results in simple more pleasing lines, in many less parts than in equivalent sawn construction, with attendant savings in assembly and in connection hardware.

The outstanding use for glulam is in the production of glulam arches, of Tudor, Gothic, or special curved shapes as is required by the architectural considerations. The ability of glulam to be built up to any size or shape is the essential constituent which sets it apart from all other forms of timber building materials, and it is through its use in arches that glulam has found its greatest popularity and most diversified use.

Other applications have resulted from the flexibility of this material. For example, timber beams are an excellent means of spanning moderate distances in roof construction. However, it is frequently necessary to provide some pitch on the roof, and often desirable to provide a vaulted interior. With glulam, the beam can be cambered to suit the architectural requirements, and can be built up toward the centre with additional material, sawn off after manufacture to provide a pitched roof and a vaulted ceiling. Such beams are usually left exposed, the natural finish of the wood lending itself to the appearance of the room, with joints providing a support for both the roof decking and for the ceiling. Often wood decking is placed directly on the beams, with additional rigid insulation on top if required, and the decking left exposed underneath to form an attractive ceiling itself. Such cambered and tapered glulam beams are, of course, more expensive in themselves than a plain glulam or sawn beams or members of other material; it is in the application of glulam and the way in which it is used together with the other parts of the structure that make possible savings by its use.

Many other structural uses, such as towers, bridges, arch centerings of reinforced concrete, and standardized light utility buildings, are good applications of glulam. Glulam can be used in conjunction with sawn members, the larger members and curved or special shapes being built of glulam, and straight members of rectangular cross section of sawn material. Many non-structural applications of glulam have also found favor with designers. Some of these are diving boards, cargo sledges, dredge spuds, mine elevator guides, ornamental lamp and sign posts, stem and keel assemblies and transverse frames for ships; new applications are being found constantly.

Glulam Service Grades and Appearance Grades

Glued-laminated members may be manufactured in either exterior or interior service grades, according to the conditions of exposure to which they will be subjected and this in turn dictates the type of glues with which they are bonded. Casein glues are most commonly used for interior glulam and resorcinol-formaldehyde adhesives for exterior grades. Urea adhesives have found little favor with fabricators.

Glulam members may be also obtained in several appearance grades

according to their architectural functions. The higher quality grades are highly sanded, with all surface imperfections removed and replaced with sound wood, and minor imperfections filled with a matching wood filler. Other appearance grades intended principally for industrial use have their edges planed to dimension, but are not sanded nor are surface imperfections patched or filled. Selection of the proper grade depends upon the use of which the member is to be put; it is usually much less expensive to specify a high quality appearance and leave the member exposed, than to specify a lower industrial-type appearance grade and cover the member with non-structural material for the sake of appearance.

Preservative Methods

For exterior use under conditions which permit decay, it is desirable to pressure treat the timber members to insure their permanence. Glulam members may generally be treated by the same methods as sawn timbers, and of course glulam members for exterior use always have water-proof glue lines. Treating cycles differ slightly because of the initial dryness of the glulam material, but the end results are the same. Waterborne treatments are generally less to be preferred than creosote or other oil-borne treatments, because of the attendant distortion of the glulam member after it has been dried back to interior equilibrium moisture content.

It is possible either to treat the finished member after gluing, or to treat the laminating stock before gluing. It is always preferable to treat a completely fabricated member, so that the preservative penetrates the connector grooves and other points of fabrication which are most vulnerable to decay. This is often impossible with curved members, however, owing to the size of the treating cylinder.

When it is necessary to treat before gluing, special precautions must be taken to insure a good bond of the adhesive. The laminations are usually surfaced hit-and-miss to a slightly oversize dimension, and an especially heavy treatment is injected. After treating, the laminations are given a final surfacing before gluing. With this method, all subsequent fabrication must be treated locally, a procedure of somewhat uncertain effectiveness.

Special handling of coatings has been used to secure special effects. In one such case, arches were stained, and a stencil was placed along the soffit corners and a portion of the stain bleached out, to give a serrated effect. Other arches have been ornamented by the use of stencils and colored paints, giving the appearance of inlaid work. Carving, beading, and other ornamental work can, of course, be carried out on the timber itself since it is dry and will remain free of checking and splits in use. Some effort has been made in combining species of high cost exterior surfaces for appearance, and materials of relatively low cost in the interior for strength. In one such case, laminations of Oak and Douglas fir were combined in this way, the soffit lamination being a single width of Oak and the remainder of the laminations consisting of strips of Oak near the edge with a Douglas fir core. Some experiments have also been made in printing grains of higher-cost woods on properly ground-coated Douglas fir.

Strength of Glulam

Glulam enjoys greater strength than sawn timber, both because of the increase in strength due to the dryness which is a primary requirement of laminating, and because of its greater homogeneity. In glulam, it is impossible for a knot to carry through more than one lamination at any given point, and knots in various laminations in the same member will be widely dispersed.

To effect the greatest economy in bending members, the highest grade laminations having the least knots are placed in the top and bottom zones where they can be most effective, and lower grade laminations of correspondingly lower cost are placed in the zone near the neutral axis. If clear laminations are available they are placed in the extreme positions, resulting in clear material exposed for good appearance as well as highest strength. In compression and tension members, the placement of grades is not of importance unless the stress in them is combined with bending.

It has often been thought by the uninitiated that the possibility of use of relatively low grades in structural members in this manner results in the manufacture of a member which is cheaper than the equivalent sawn member. This is not true, however, as there is no strange alchemy by which one can take inferior grade material of small size, glue the pieces together and obtain a superior product. The grades of material used must be of sufficient quality for the job in hand in order to obtain the quality product sought.

Glulam Specifications

When glulam first became used in Canada and the United States, a blanket increase in working strength above that of sawn timbers of equivalent grade was included in some building codes and specifications in recognition of its superior strength. Sufficient experimental data was not available to arrive at any theoretically correct values, so all allowances by specifications were necessarily conservative.

No time was lost in starting the necessary laboratory work toward arriving at proper theoretical and practical design standards. Much time was needed, however, for such a study, and it was carried out over a period of several years by the U. S. Forest Products Laboratory of Madison, Wisconsin, in conjunction with the National Lumber Manufacturers' Association and the various regional lumber manufacturers' associations concerned.

In Canada, work was carried out along parallel lines at the Forest Products Laboratory at Ottawa. There, tests were made and results carefully compared and exchanged with the Madison laboratory. These findings have been used in setting forth requirements in the recently-published C.S.A. Specification 0122 (1953), *Specification for Glued Laminated Timber Construction.* This specification embodies the results of the most advanced research in the subject, tempered by practical common sense, and is the only known specification in effect today which provides for all the principal species and allows wide flexibility of design.

In developing this specification, it became apparent that in order to cover the wide scope of species necessary, the specification had to set forth the method by which working stresses could be found rather than the end results, since years of calculation and volumes of tables would have been necessary to accomplish this feat. It is possible to design directly from the specification, but its rather cumbersome mathematical approach indicates the need for supplementary shortcuts which can be developed easily for particular species and specified combinations of laminating grades. This development is the responsibility of the lumber associations and the manufacturers of glulam.

Laminating Grades

Since grading rules differ widely among the various species, it was first necessary to set up special laminating grades similar to the tension grades set forth in the C.S.A. Specification for structural timber, with characteristics assigned to these grades which are pertinent to glulam construction. Formulae were then developed as a result of the tests conducted at Ottawa

and Madison, and were used in the specification for determining the working stress in bending, compression parallel to grain, compression across grain, tension parallel and across grain, and horizontal shear, from basic stress tables given in the specification.

Basic stresses in glulam are defined as safe working stresses for clear, unscarfed, straight grained material free from any defect affecting strength. Working stresses are developed from these basic stresses, by reducing them in accordance with the strength-reducing character of the natural growth characteristics specified by the grade. The principal defects affecting strength are knots, slope of grain, shakes, checks or splits, and the density of material as determined by rate of growth. The ratio of the working stress for a particular laminating grade to the basic stress for the species is termed the strength ratio of the grade. Under the C.S.A. Specification, four laminating grades have been established, having strength ratios of 90%, 75%, 60% and 50%.

Placement of Knots

In order to control the placement of knots and thus permit reasonable design assumptions, it is necessary to control the placement of defects in laminations in the actual gluing process. One method of doing this is to limit the total number of knots in any cross section; another is to specify that knots must not be present at the same cross section in adjacent laminations. If none of these assembly methods is considered in design, and no statistical study of knot frequency has been made, the designer has no alternative but to assume that all laminations will possess a maximum knot at the same cross section, located at the point of greatest stress. This can never actually occur in practice, and a reasonable requirement as to knot segrègation must be made in design which is feasible in actual assembly. Several possible such methods of assembly with corresponding design assumptions and assembly controls are set forth in the C.S.A. Specification.

Design of bending members under the C.S.A. Specification is accomplished by using the basic bending stress for the species and the net effective moment of inertia for the cross-section of the member, after all knots present at any one cross-section have been deducted. By proper assembly controls, limitation of knots at any cross-section can be assured to agree with the design assumption. Structural designers are accustomed to using a working stress applied to the gross moment of inertia of a member, however, and for any given combination of grades and method of assembly an equivalent working stress can be worked out which may be used with the gross section in designing. Using such a method the greater the number of laminations, the more nearly the working stress will approach the basic stress of clear laminations as given in the basic stress tables. Published working stress tables must then be based upon a set number of laminations, with all members having more laminations than this fixed number suffering a slight penalty. In actual practice this penalty is small and is compensated for by the simplicity of the system. Structural timber technicians may still take advantage of this property when they wish, however.

Inspection and Testing

An essential part of development of the present C.S.A. Specification was the recognition of the fact that, once laminated, it is impossible to tell the nature of the interior of a glulam member from its outside appearance. Glulam is much like a welded assembly in that its strength and safety depends upon the quality of the material incorporated and the skill of the laminator. The reputation of a responsible concern is always the best assurance of quality of product. In welding this is recognized by the establishment of the Canadian Welding Bureau and their certification of approved welders.

It was felt, however, that the establishment of an equivalent to the Canadian Welding Bureau for glued-laminated construction was a large step at this time. In lieu of it, a method of inspection and testing was made a part of the specification so as to set uniform standards for manufacturers' workmanship certificates and as a guide for an independent testing laboratory in the event that one was required. The marking of laminating grades under these standards and the method of assembly into beams makes it possible for an inspector at a laminating plant to spot-check certain features of the process and assure that the manufacturing procedures of the laminator will result in a product of the required quality. In addition, certain tests of samples of the material are set forth, for use when desired, in much the same manner as concrete cylinders are tested after the material is in place, to assure the adequacy of the bond. For interior grades, these consist of a block shear test, and for exterior grades, using waterproof glues, a three-cycle vacuum-pressure delamination test is specified.

The provisions of the C.S.A. Specification for Glued Laminated Timber Construction both as to material and design have been incorporated in the forthcoming new edition of the National Building Code of Canada. It is expected that many municipal building codes which are now in process of revision will follow the National Building Code and thus the C.S.A. Specification in this regard. Thus we may expect in a relatively short time to have what amounts to a nationally uniform specification and practice for sawn and glued-laminated timber construction in Canada, and which is only now approaching accomplishment in the U. S. A.

Manufacture of Glulam

Reduced to its barest essentials the manufacture of glulam consists of gluing boards together to make timbers. Since those timbers must support heavy loads, however, and since life and property often depend upon their reliability, careful control of conditions in manufacturing are essential.

Although casein glues are very easy to work with and require a minimum of close technical control, some of the waterproof glues require especially careful control of conditions in assembly, spreading, clamping and curing. In all cases, moisture content and temperature of the laminating stock, proper glue mix, adequate glue spread, proper open assembly time, adequate clamping pressure, and proper curing temperature, time and humidity are essential to the production of glued-laminated members of good quality. In addition, dimensional control of laminating stock must be carefully controlled to assure uniformity and good glue bond.

Types of End Joints

The end joints of laminations are commonly made by scarfing, either a plain scarf or a hooked, stepped or serrated scarf. The plain scarf has the advantage that it transmits stress with the greatest efficiency, and a scarf with a slope of 1 in 12 is 90% as strong as the clear wood in which it is made. Steeper scarfs have lesser strength. However, the plain scarf must be carefully positioned so as not to override or underride its mate, causing lack of glue bond with the laminations adjacent to the scarf joint. This positioning problem can be overcome by the use of a stepped or serrated scarf, but such a scarf, even of the same slope as a plain scarf, has less strength than the plain scarf. The reduction in area of the step must be considered cumulatively with the reduction in strength owing to the scarf, and thus a stepped scarf having a single step of 1/10th the thickness of the lamination would

have only 90% of the strength of the clear wood in which the scarf is made, 81% of the basic lamination strength.

This is not necessarily a limiting factor, as the strength of the laminations is usually limited by grade and may be lower than the scarf strength ratio so obtained.

Since practical lamination of curved glulam calls for bending the laminations dry, the thickness of the lamination is controlled by the radius of curvature. It is of course possible to pre-bend the laminations by steaming followed by drying to proper gluing moisture content, but this process results in raised grain, some falldown in grade, and other undesirable features, as well as leading to difficulties in glue spreading.

It should be noted that standard thicknesses of laminating stock are 1⅜" and ¾" for Western softwoods. The use on architectural design of radii requiring thinner laminations means that standard laminating stock will have to be planed down to the required thickness with the waste going out as shavings. For example, a Tudor Arch designed for radius of curvature of 5′ will require ⅜" laminations, whereas one having a radius of 9′ 4" would require standard ¾" laminations. The arch with 5′ radius would take about twice the board footage of lumber and twice the glue for the same structural size, with attendant higher cost.

Moisture Content

Proper moisture content for gluing must be maintained in all laminations. Codes and specifications generally call for this moisture content to be within a range of seven to sixteen percent, with a maximum variation of 5% between the wettest and driest pieces in the assembly. This is not a critical condition and is usually easily met. With waterproof glues it is desirable to maintain the moisture content of adjacent laminations within a closer range in order to obtain good bond.

The manufacture of a glulam arch presents an interesting study in coordination. After detailed drawings of the arch and material schedules have been prepared by the engineering department and approved by the customer or his architect, full-sized plywood patterns of the arch are made up and the required number and length of laminations is noted. The required quantity of laminating stock of proper thickness is then scarfed at both ends, and this scarf material is assembled in a dry layout, each lamination being cut to full length and piled in order, with the scarves loosely joined without glue. Control marks are placed on the edges of these laminations to aid in proper assembly.

Forms for the arch are then set up according to the pattern and when all components have been prepared, the laminations are run through a glue spreader and laid alongside the form ready for clamping. It is at this stage a control of assembly as to knot placement is exercised, and if knots are present in adjacent laminations, one lamination can be laid aside.

Pre-glued Joints

In some operations the scarf joints are pre-glued with electronic or direct heat machinery to form one complete lamination of full length. In such processes it is important that no glue be allowed to squeeze out beyond the ends of the scarf joints, thus forming a hard bead which would prevent proper contact of adjacent laminations and therefore result in inefficient bonding. In other operations, the glue is applied to scarf joints immediately before assembly in the arch, and the scarves are temporarily fastened together as they pass through the glue spreader. In every stage of the operation it is important that the moisture content of all laminations be within the limits specified and the laminating stock must therefore be tested for moisture content before dry lay-up. It is likewise important that uniform thickness of laminations and of the scarves joining them be maintained so that proper contact and pressure will be maintained between adjacent laminations and a good bond secured. Most specifications, including the C.S.A. Specification, call for a maximum variance of 1/64" between pieces in lamination or between total thickness of joint scarves and the lamination itself. This is a tolerance much less than that usually permitted in lumber manufacture.

The gluing and clamping process must proceed without delay so that proper assembly times will be observed. After all laminations have been spread with glue and laid in their proper relationship, clamps are applied near the center of the arch to pull the laminations into the form and to gain the required pressure. Clamping then proceeds outward toward both ends simultaneously, drawing the arch into the form and at the same time providing pressure. Intermediate clamps between form members are frequently applied in order to gain uniformity of pressure throughout the length of the arch.

Finishing

After the proper curing time under pressure has passed, the clamps are broken down and the finished arch is moved to a saw which cuts according to patterns, the proper shape of the back, which will ultimately form the wall and roof planes. The arch is then surfaced on both of its side faces, either by portable planers or, if feasible, by passing the arch through a stationary planer. Imperfections which may appear in the faces are removed and replaced with sound stock; all blemishes are filled with a matching wood filler, and the entire arch faces and soffit are sanded to their final finished appearance.

After manufacture, the pattern is again placed on the arch and its ends are trimmed to the required shape, and holes, grooves, and other fabrication is completed. The arch is then piece-marked as to its location in the structure, and its highly sanded surfaces are protected in shipment by a wrapping of specially prepared paper, and when necessary crating to protect the corners. The finished glulam arch is more than a structural component: it is also an architectural feature and therefore must be treated with the same care as a door, a window, or any other piece of finished millwork.

Future Research Needed

Although timber has advanced far toward regaining its true position as a structural and architectural material, many questions yet need to be answered, and much improvement can be made in its manufacture and use.

With an increase in volume of production, better manufacturing methods can be worked out which will result in lower costs and quicker delivery. Manufacturing methods will always differ in various parts of the country and with various species and uses, but machinery and processes can be developed which will greatly reduce the individual hand operations. One continuous press has been used which carries out the functions described in the manufacture of the Tudor arch previously referred to, in one continuous operation, making a continuous circular glulam member of small size for light buildings which is trimmed to lengths required as it moves out of the press. Machinery is now in use for the rapid manufacture of full-strength laminations of unlimited length by scarfing together individual pieces, and similar machinery has been developed for edge gluing when required.

A means of rapid glue curing of large straight members is desirable to speed shipments, to cut down clamping labor and to reduce the amount of space required for curing members

(Continued on page 88)

The HB System of Nailed Laminated Wooden Beam Construction[1]

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Explains method of fabricating long beams and rigid frames from short lengths of one inch boards. Joints are primarily made by nailing. Permits use of common grades of lumber. System is practical with inexpensive shop and equipment. Advantages of system are explained.

FROM SWEDEN, a country small in size yet progressive in technological and scientific development, has come a significant contribution to long-span wooden beam construction; development of the HB Beam System. In its basic form, the HB Beam is a laminated wooden beam in I-section form, having a web and flanges joined by a system of nailing. Although this basic form has been used experimentally in various other instances, the unique contribution of the MB Beam System is the development and refinement of techniques for constructing long-span beams and rigid frames practically and economically entirely of short lengths of 1″ boards, joined largely by nailing. The inventor of these techniques is Professor Hilding Brosenius of the Royal Institute of Technology, Stockholm, and Director of Research and Development of the HSB Building Association.

The webbing of the basic form of the HB Beam consists of two layers of boards, usually 1″ thick, inclined diagonally to the length of the beam, the members in the two layers being sloped in opposite directions so that they cross at approximately right angles. Each flange consists of two identical timber sections (usually built up of short boards to sufficient continuous size by a simple gluing process) which are placed on each side of the web and attached by a specially calculated system of nailing.

Widely Used in Europe

Far from being experimental, the HB Beams are produced in large quantities in Sweden by the HSB Building Association of Stockholm, one of Europe's largest construction enterprises. Since its inception in 1939, the HB Beam System has been employed in the construction of more than 2,000 structures in many parts of the world (for example: Sweden, Norway, Finland, Holland, England, Germany, Arabia, Australia, and recently the United States[2]) with noteworthy success. The HB Beams are either exported to or manufactured in these countries by licensee firms.

Particularly significant of the applications of the HB Beams is their demonstration of amazing versatility. Included among the types of structures incorporating HB components, one finds warehouses, theaters, gymnasiums, garages, storage sheds, barns, bridges, dance halls, sports arenas, military training halls, etc. More than 75% of all the aircraft hangers built in Sweden during World War II, both for military and civil airports, have used HB Beams in their construction.

Readily Adaptable

In the structures in which they are used, the HB Beams are unique and distinctive architectural features which lend themselves to various treatments: varnishing, staining, painting, boxing, or paneling with plywood or decorative woods, etc. Traditional, rustic, or modernistic effects are equally easily obtained. Where the beams are exposed to severe weather conditions (as in bridges), the beams are simply treated with one of the many types of weatherproofing on the market. The HB Beams are attractive enough to be featured in an auditorium and yet economical enough to find application in a factory or warehouse. Such distinguished architects as Professor Nils Ahrbom of Sweden and Alvar Aalto of Finland have specified HB Beams in some of their buildings.

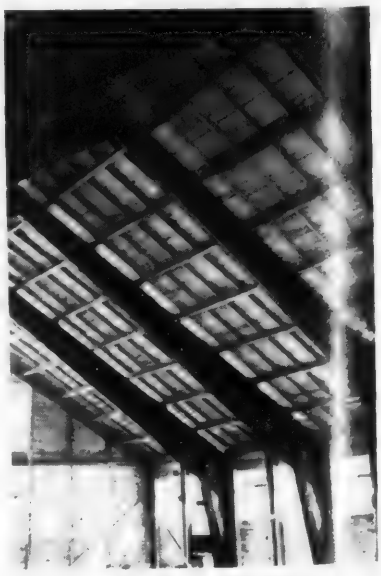
The HB Beam System can be adapted to straight or flat-topped beams or to two- or three-hinged rigid frame arches of almost infinite variability as to size and strength. In the construction of portal and arch frames, a feature of the beams has made it possible to deliver the beams in prefabricated straight lengths, to be joined on the site by a simple nailing process. The use of web stiffeners of different types also has made the production of deep beams at low cost a practical matter. The development of a special splice joint for simple joining of prefabricated sections on the building site has made the construction of continuous beams exceeding 300 feet a practical proposition.[3] Another development allows the interlacing of primary and secondary beams, much like welded steel construction, without loss of structural strength in either beam at the point of cross. The flanges of all beams and their fastening to the web comprise a special combination of gluing and nailing, which simplifies manufacturing and at the same time gives high strength to the beam. The special features of the HB Beam System are covered by patents and patent applications in many countries, including the U. S. A.

The economy of the HB Beams in comparison with other types of sub-

[1] Presented at meeting of the Forest Products Research Society, Northeast Section, Dec. 4–5, at New York City.

[2] It should be noted that the first and, as yet, only structure in the United States built with HB Beams is the theater in Naples, Maine, illustrated in Progressive Architecture, July, 1952, pp. 106–7.

[3] One such tremendous beam is in a hangar built for the Swedish Air Force having a span of 361′ continuous over two supports. This primary beam supports secondary beams 131′ long, including a cantilever section 40′ long which horizontally supports the hangar doors.



Three-hinged rigid HB frames.

st:ute constructions varies within certa limits, depending on various fac- tor such as span, load, cost of trans- po ation, price and supply of other st tural materials, etc. An exact com- pa son cannot therefore be based on or one or two constructions or by m ing comparative cost calculations of he HB System with some other co peting method. The experience of th HSB Building Association in Sw den, through the construction of ov 2,000 structures and the bidding on many more contracts has shown tha as a rule, the HB Beams are usually cheaper than both bolted wood and steel structures, the price differential fluctuating between 10% and 50%, in certain cases.

Low Dead Weight

In comparison with equivalent steel beams and girders, HB Beams have a very low dead weight: for medium and long spans, the weight is approximately 60% of that of the equivalent steel structure. This makes it easier to handle and to erect, and also it has the additional advantage that it can be worked on with ordinary woodworking tools. The erection on the site can be executed simply by a nailing procedure, which reduces erection costs considerably.

Besides the direct costs of manufacturing beams, the relative economy of the HB System is highly influenced by the often immeasurable indirect costs, which are often considerably lower for the HB System. A few examples of the areas where indirect economies occur may be cited.

HB Beams show considerable reductions in overall dimensions and dead weight compared with timber framed girders of equivalent strength. These factors enable appreciable reductions to be made in the outside dimensions of a building for any given effective internal volume, which not only reduces the total cost of the structural materials, but also reduces the cost of heating the building, as the total volume will be decreased.

A further consideration is that maintenance work on the bolted connections of framed structures, which is frequently costly and difficult, is rendered unnecessary when using HB construction.

Framed structures are also usually more costly than equivalent HB Beams due partly to the cost of forming the bolted connections, and partly to the necessity for under-stressing the majority of the timber in order to avoid over-stressing at the joints. This latter consideration does not apply to the same extent in HB Beams and thus a considerably more rational use of the timber can be made.

Less Design Work

The cost of engineering work in designing and constructing HB Beam structures is considerably lower than those for framed structures. The HB Beams can be calculated with the aid of tables in the same way as, for example, steel I-beams. Framed structures of wood or steel, on the other hand, have usually to be designed individually for each structure. The difference in engineering work is of considerable practical significance, because the simple method of calculating and designing HB Beams is an important feature in the factory production of the beams. An HB factory should require only one-third or one-fourth the staff of engineers needed in a comparable framed structure plant.

It should be understood that especially in long-span constructions, the work in the construction office and the erection on the site requires careful supervision of skilled engineers. When large HB Beams are used, only minimum supervision and inspection on the job is necessary, as the difficult work is done at the plant under controlled conditions. Also in the factory, mainly unskilled labor is used in the manufacture of the beams; only a few skilled workers and foremen are needed.

Simple Shop Requirements

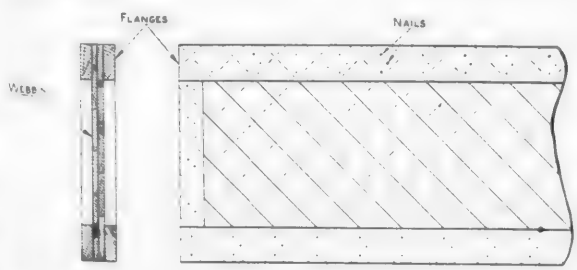
The production of HB Beams is rather simple, and no complicated processes are involved. For best results—economically and technically—however, it is best if the manufacturing can be done in a workshop suitably equipped with certain machines. HSB's own workshop is 80′ x 130′ and is able to produce HB structures containing approximately three million board feet of lumber annually. The shop contains saws, moulding, and planing machines, glue mixing and spreading machines, glue presses, portable saws and drills, and pneumatic hammers. A portion of the shop is set aside for gluing of the flanges, which is the operation requiring the most care, although the methods are quite simple in themselves.

The machinery needed for the manufacture of the HB Beams can be varied within very wide limits. For the most simple factory, only the glue presses for the manufacture of the glued flanges are required. HSB began with such a minimum of equipment when the first HB Beams were produced. The machinery can then be added piece by piece, until an up-to-date shop is in operation, insuring greater output capacity and a higher standard of uniformity.

The webbing boards and the glued flanges are assembled exclusively by nailing with rather long wire nails following certain predetermined patterns. The nails are driven easiest with pneumatice hammers, for which the workshop should also be furnished with compressed air equipment. The assembly of the beams is completed by nailing on the web stiffeners, adjusting the flanges, etc. The HB Beams are of so compact and solid construction that usually no wrapping or other protection for shipping is needed. As it is impractical to ship lengths exceeding about 80 feet, the frames are usually shipped in lengths not exceeding that size for easier handling. The parts are easily assembled on the job by nailing, as previously mentioned.

Ordinary Lumber Used

The production of HB Beams can be undertaken even in countries and areas where high grades of lumber are not available or too expensive, since the HB System is designed to use the ordinary grades of lumber, spruce, fir, or the pines are usually used. Kiln drying is not necessary or even recommended. In Sweden, the HB Beams are manufactured of short length (average 14′), air dried spruce with a moisture content of 18–20%. The HB System thus provides a means for obtaining the maximum utility from lumber which is not ordinarily considered suitable for long-span beam constructions.



Typical two-hinged HB portal frame (above).

Typical section of an HB-Beam (left).

Trends In Structural Practice[1]

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Author reviews basic trends and engineering data that have made wood more available for structural uses. More precise grading, mechanical improvements such as better joints, glued laminating and prefabrication have all played a part in improved use of wood for structural purposes.

IN ORDER TO PROPERLY evaluate contemporary trends in structural practice, it is necessary to review the history and background of some of those trends. The history of structural practice in the timber industry is generally recognized to be one of continued progress. In the early days of this country a great deal of progress was due to the use of timber to build railroads, schools, churches and homes. The fact that a number of these early structures are still standing testifies to the sterling qualities of the timber used and the practical know-how of the constructors.

For a period of time, shortly after the advances of steel and concrete in this country, the use of lumber for heavy structures was pushed into the background. This was due more to the lack of design knowledge and the weakness of timber joints, especially in tension than anything else. The impossibility of the early fastenings to develop the full strength of the members in tension in an efficient manner was a decided drawback. Great bulk in the members were required to accommodate the fastenings. This bulk, of course, increased the material and labor costs and all designs resulted in a tedious process of fabrication and assembly. There are many reasons why timber has forged ahead since around the early 1920's.

Two things happened to add impetus to more construction with timber. The first of these was the experimental introduction of timber connectors into this country in the twenties and the subsequent introduction on a commercial basis in 1933. Engineers immediately found a new system of timber construction available which increased the strength of bolted joints, made good tension members practical, and made structural members smaller because the joints could develop the full strength of the member.

There was, in 1925, no uniform practice in timber engineering based on research of any consequence or common experience. Each designer relied upon his own particular personal experience and judgment. In the meantime, the second series of events were significant. Clear specimens of timber, not used in timber construction, had been tested and the results of over 100,000 tests were reported by J. A. Newlin and T. R. C. Wilson. These tests established a firm foundation for other research. New life was given to timber construction in 1925 when Herbert Hoover, Secretary of Commerce, established the National Committee on Wood Utilization. Various studies were made under the guidance of this committee, and the Forest Products Laboratory published in 1930 the results of the two studies—one by L. J. Markwardt on the comparative strength properties of timber in the United States, and the other by J. A. Newlin and J. M. Gahagan which presented a dependable timber column formula. Definite information also became available in 1932 from a report by G. W. Trayer on the bearing strength of timbers under bolts which was followed by similar studies on the strength of nails and screws in wood. Thus, at the same time that timber connectors were introduced commercially, the American engineer had available the necessary standards, based on authoritative research, to enable him to design in timber with the same feeling of security as with any other structural material. It was natural that engineers and contractors would soon find that timber trusses designed with the new timber connectors were not so tedious in assembly as the old block and rod truss. This speed of construction immediately became an asset to timber construction and still is a great factor in its favor.

Slowly but surely in this country there was to develop a timber prefabrication industry which would add further information to the general knowledge because of the inherent competition and would add to the speed of construction. Material could be fabricated under assembly line methods in spite of weather and could be more easily adapted to custom built structures.

World War II found the lumber industry well prepared to do one of the biggest jobs in its long career. Before actual war was declared, the timber industry had participated to a great degree in the Defense Program and had proven its value. A great number of buildings were built with timber trusses of long spans never dreamed of before. Uncounted buildings with prefabricated timber trusses were built more speedily and more efficiently than had ever been done before. This record firmly entrenched the truss fabrication industry, added more knowledge to the art of designing in wood and taught engineers and architects the best methods of designing.

Perhaps the greatest advance in structural practice in connection with wood in recent years has been in the glued laminated field. Properly glued arches, beams and columns offer a medium of construction suitable according to the degree of finish desired for factories, schools or churches. The bending of wood to shapes and gluing with the initial internal stresses dissipated shortly after the bending is an extremely interesting phenomenon and at the same time is furnishing practical, attractive and economical structural frameworks. Fabricators of glued laminated material are consistently learning more about mechanical handling of their material which will reduce hand work, are using better glues and are developing designs which are more economical. Not so long ago, for construction purposes, no lumber was considered to be worth much more than 1200# per square inch, fibre stress in bending, but you will be interested to know that specifications have been written by both the West Coast Lumbermen's Association and the Southern Yellow Pine Association, specifying acceptable fibre stresses up to 1800# per square inch. Actually, most glued

(Continued on page 89)

[1] Presented at meeting of Forest Products Research Society, Northeast Section, December 4–5, 1952, at New York City.

Lumber Grades For Military Packaging[1]

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Relates study to determine most economical grades to meet government specifications for military packaging, particularly as regards use of low grade material with considerable waste as compared with more expensive grades with less cutting waste.

THE GOVERNMENT DOES not specify in so many words the grade of lumber to be used in the construction of overseas shipping containers. The manufacturer is given a chance to decide within certain limits what grade of lumber he wishes to use. Control on the quality of product is maintained through other means. For this discussion only, let us consider the two types of wooden exterior containers that are used in the majority by the Military, namely, Nailed Wood Crates made in accordance with Specification JAN-P-104 and Nailed Wood Boxes made in accordance with Specification JAN-P-106.

Both of these specifications cover the subject of lumber grades by specifying definite limits for the various defects that occur in lumber: for example, the size of knot permitted, the divergence of grain permitted, and a sort of catch-all phrase which states that the material shall be sound and free from all defects that may weaken the material or interfere with the prescribed nailing. By doing it in this manner rather than by specifying a specific grade of lumber to use, the government feels that it gives industry sufficient leeway to use all possible resources at its command and still produce a product that the government will accept.

The remainder of this discussion will center around the problem of trying to determine the most economical grade of lumber to use in the making of containers. It must be conceded at the start that the most economical grade of lumber to purchase for making containers is the one that yields the lowest net cost per container.

[1] Presented at meeting of the Forest Products Research Society, Midwest Section, Oct. 31–Nov. 1, 1952, at Ann Arbor, Mich.

To try and obtain an answer to this problem, the Forest Products Laboratory conducted a study for the Corps of Engineers. The Corps of Engineers was interested in the problem because they are the single purchasing agency for lumber for all Department of Defense installations and their records indicated that approximately 60 percent of the lumber purchased by them was for the construction of containers.

Forest Service utilization data indicated that over 80 percent of the softwood lumber used in containers came from the following five species: ponderosa pine, southern yellow pine, Douglas fir, hemlock, and white fir. Lumber yields and cost studies were made for various grades of these five species of wood for the following three common sizes of Style 4 nailed wood boxes:

Box Size	Inside Dimensions (Inches)		
	Length on end	Width on end	Depth on end
Small	11	8	8
Medium	24	14	12
Large	32	15	16

This study was made at a Military installation that was actually making boxes so that the actual time required in the cross cutting, rip cutting, and various nailing operations required in the making of a box from the different grades of lumber could be determined. The number of boards and the amount of lumber studied in each species is shown in the following tabulation:

Species	No. of Boards	No. of Bd. Ft.
Southern yellow pine	1,130	18,000
Douglas Fir	1,772	16,175
White Fir	2,520	24,044
Ponderosa Pine	2,120	20,270
Hemlock (West Coast)	2,521	20,412

All of the boards studied were nominal 1-inch thick, varying in width from 6 to 12 inches and in length from 6 to 18 feet.

It is well-known that the greatest yield of usable material is obtained from Grade 1 lumber and that yield decreases as the grade of lumber decreases. This fact was borne out by the study, as the figures in Table II indicate.

Another accepted fact is that it takes considerably more time to cut acceptable material out of the lower grades of lumber because each piece requires the operator to make an individual selection. Because of the time consumed, this operation adds considerable cost to the making of a box.

(Continued on page 89)

Table I—COMPARISON OF YIELDS OF BOX PART (PER CENT)

Species Studied	Grade Lumber				
	1	2	3	4	5
Douglas Fir	79.6	76.7	71.1	60.2	----
Southern Yellow Pine	81.9	75.5	71.1	63.2	----
Hemlock	81.1	78.7	72.1	60.6	----
Ponderosa Pine	80.8	78.7	76.5	71.1	58.3
White Fir	82.5	79.4	77.6	71.0	55.5

Table II—COMPARISON OF COST OF BOXES

Douglas Fir		Hemlock		Ponderosa Pine		White Fir	
Grade No.	Percent	Grade No.	Percent	Grade No.	Percent	Grade No.	Percent
1	5	1	5	1	1	1, 2 & 3	34
2	3	2	3	2	11	----	----
3	5	3	5	3	20	----	----
4	2	4	2	4	13	4	11
----	----	----	----	5	2	5	2

xInformation provided by West Coast Lumberman's Ass'n., and Western Pine Ass'n.

Table III—PERCENTAGE BREAKDOWN OF COMMON BOXED GRADES OF LUMBER[2]

Species Studied	Grade 1		Grade 2		Grade 3		Grade 4		Grade 5	
	Lumber Cost	Box Cost	Lumber Cost	Box Cost	Lumber Cost	Box Cost	Lumber Cost	Box Cost	Lumber Cost	Box Cost
	Dollars		Dollars		Dollars		Dollars		Dollars	
Douglas Fir	112.50	2.28	108.00	2.27	90.00	2.15	52.25	1.80	----	----
Southern Yellow Pine	125.00	2.43	110.00	2.36	101.00	2.36	58.75	1.88	----	----
Hemlock	105.00	2.14	102.00	2.13	92.00	2.17	51.25	1.78	----	----
Ponderosa Pine	140.00	2.69	127.50	2.52	108.00	2.28	90.00	2.16	60.00	2.01
White Fir	110.00	2.18	110.00	2.25	102.50	2.17	85.00	2.07	57.00	2.01

Industrial Packaging Problems[1]

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As dispersion of plants manufacturing component parts of automobiles increases, "behind-the-scenes" industrial packaging requirements multiply. Such packaging is critical since damaged parts arriving at assembly plants can slow down production. Shipping costs also soar when damaged parts must be returned for repair.

GENERAL MOTORS defines packaging as follows: "the art or operations required in the preparation of goods for shipment, storage and delivery to the consumer. It involves protection from deterioration, mechanical damage and pilferage. It requires the use of container materials and facilities for the production and handling of packages and consideration of distribution and merchandising aspects."

The term "industrial packaging" as herein used refers only to packaging operations as they are used in the production and manufacturing phase of the Auto Industry rather than in the sale and distribution of any finished product to the general public.

Most industrial packaging operations are performed "behind the scenes" as far as the general public is concerned, yet these Packaging Operations coupled with those of transportation and Materials Handling are an important part of the final cost of any finished product.

Industrial packaging problems are constantly becoming more complex because of the rapid progress and expansion of the auto industry; and the dispersion of manufacturing plants throughout the country. Parts, materials, etc. must be packed and shipped many times from plant to plant during manufacturing processes even before they reach their final destination as a finished product.

Each and every automotive manufacturing plant, whether it be producing a finished product going to the consumer, or whether it be producing only component parts which are shipped on to another assembly plant has two important phases of materials movement which present many and varied problems of industrial packaging. These are:

First—Incoming Shipments from supplier plants of productive parts assemblies, materials and non-productive supplies.

Second, Outgoing Shipments of parts and products which this plant manufactures or processes.

The Packaging Problems presented by each of these phases of material movement are usually the same.

What about these so called "behind the scenes" packaging operations; how are they related to materials handling and transportation; what is required to insure a smooth and even flow of materials movement in the auto industry?

On the average it takes about six distinct steps or operations to take any automotive part or assembly such as a carburetor, from its last final production operation in a supplier plant to a user plant. These are:

1. **Packaging**—Place in carton, box etc., and make up palletized unit load.
2. **Transport** to warehouse or "Float" storage adjacent to shipping area.
3. **Remove** from "Float" area and load on truck or freight car in shipping department.
4. **Ship** via Carrier to user plant.
5. **Receive** at user plant. Remove from truck or freight car and transport to float storage.
6. **Remove from "Float"** and transport to using point where part is removed from package and again goes into production.

In addition to these six physical moves of the part, there is a large amount of paper work involved in the transfer, such as shippers' bills of lading, receiving reports, inventory records, etc.

All these six steps or operations have a direct affect on cost and product cost is one of the number one problems before industrial management in today's competitive market.

You will note that Packaging was number one of the six necessary steps required to move parts and material between plants. This in itself shows the importance of industrial packaging and the immensity of its problems in the automotive industry. Should any specific part be improperly packed and thus become damaged in any of the subsequent materials handling or transportation operations, the damage is often not discovered until the part has reached its destination and been unpacked for use. What happens? If the part is damaged beyond repair, the entire net cost of the "packaging-material-handling cycle" has been lost plus the total value of the part itself. Now suppose this part can be repaired and is not a total loss, which is usually the case. Two complete six-step "packing-materials-handling" and transportation cycles must be added to the cost of this part, as it must be repacked, shipped back to the supplier plant, repaired, packaged again and reshipped to the user plant. Assume that this part is being packaged in the same package or unit load and shipped to six different user plants at an average daily volume of 500 pieces to each plant or a total of 3,000 pieces per day. The results of improper packaging would be very expensive.

So far, we have outlined the general problems regarding industrial packaging facing the auto industry today. It now becomes apparent that a technical or engineering approach must be essential to the job to be done.

Let's see what is required to design the pack and set up packaging specifications for a part to be produced in volume. As in planning any phase of production, the man responsible for packaging must first get the facts. Now assuming that he has samples of the part as well as complete detailed blue prints giving weight, material specifications and other needed details for a pack-

[1] Presented at meeting of the Forest Products Research Society, Great Lakes Section, Oct. 31-Nov. 1, 1952, at Ann Arbor, Mich.

age design, he must also assimilate the following information before the packaging method can be set up.

1. **Production Schedules**
   What volume of parts will be shipped per day, or per week?

2. **Monetary Value of Part to be Shipped**
   The value of the part must be known in order to determine the approximate maximum packaging cost to be allowed per part.

3. **Materials Handling Operations**
   After the packaging operation, what moves are made and how many? Is there a warehouse or storage operation required? How long a time are parts stored? What type of material handling equipment will be used for each move? It is also important that this same information be secured on the plant to which these parts will be shipped, as the package must be designed to fit the methods in use in both plants. (supplier and user)

4. **Transportation Shipping**
   Will shipments be made by rail, truck, boat or air or any combination of these? Are individual shipments to be car loads or less than car loads? What specific carrier rules or regulations must be complied with, and what climatic conditions—heat, cold, humidity, etc., will be encountered?

After accumulating necessary information for planning the packaging method, the following decisions must be made in connection with the actual design of the package.

1. **Preservation**
   What cleaning and preservation operations, if any, are required before parts are packaged?

2. **Packaging**
   Which of the following general packaging methods will be used?

   A. **Individual Box or Carton**
      Parts to be packed in boxes or containers and shipped loose as completed packages. Boxes to be considered expendable when unpacked.

   B. **Returnable Shipping Containers**
      Parts to be either placed loose in containers or packed with special interior dunnage. These containers must be constructed so as to be handled by fork trucks and tier in storage.

   C. **Palletized Unit Loads**
      These may be either individual packages placed in layers and secured to pallet by gluing or banding to form the unit load or special types such as sectional tray packs, etc., which are packed as one complete unit instead of being made up of individual cartons.

   D. **Miscellaneous; crates, bundles, bags etc.**
      This method is very rarely used in production due to the large amount of manual labor required in preservation and packing.

3. **Packaging Material**
   Material specifications as to types, grades, etc. must be selected for the packaging method to be used.
   What materials are to be used for preservation, inner cushioning individual boxes or containers and pallets or shipping containers?
   Material selection must be based on utility, availability, and cost. Selection must be also tailored to the specific packaging method to be used.

Considering what is required to set up and design a packaging method; and the extreme importance of proper packaging and product protection throughout industry, it is evident that the men responsible for packaging and material handling must fully understand the entire production processing and distribution plan of their company and its products.

They must also make a careful analysis of all packaging and material handling methods, not only in their own plant but also in supplier plants and user plants to whom their products are shipped.

Industrial packaging, its related phases, and all its problems has now changed from the second to the first team organization in importance in today's industrial scheme. Good packaging and proper product protection is an important tool to help modern industrial management move ahead to new records of high production, with improved quality at lower cost.

THE FICTION: Treatments weaken structural timbers.

THE FACT: The fact is that treatments, either water or oil bourne, are not considered as weakening the strength of structural timbers.

National Design Specification permits the same working stresses for lumber impregnated by an approved process and preservative as is used for an untreated timber.

Water bourne treatments increase the moisture content of the wood temporarily and of a consequence the strength is somewhat reduced temporarily. As the framing dries the strength returns to normal.

Preservative treatments that eliminate decay and insect hazards, permit the timber to retain its natural strength throughout a longer time. Fire retardant treatments give a longer life expectancy for the strength, should fire threaten.

Wood preservers have always recommended incising for Douglas fir timbers but not for those of southern yellow pine before applying creosote treatments in closed retorts. The distinction is based on experience which finds that pine treats well without incising where fir does not. Such distinction applies to sawn timbers and it is now found that glued timbers of Douglas fir, because of greater dryness, treat satisfactorily without incising.

Doubtless, incising, which uses knives to cut some of the outer fibers, does weaken the timber slightly. Limited tests indicate a possible ten per cent decrease in bending strength. Percentage would vary for different sizes of beam, being less in large than small timbers. . . . from Tim–Press, Timber Structures, Inc.

Wood Piles—Specifications and Mechanics[1,2]

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The function of a pile is defined and current specifications and their differences are reviewed. Relative strengths and stiffnesses in static bending of different piling species, and their supporting strengths when acting as columns, are discussed. Types of loading static and impact—which may be vertical or lateral are explained. Bending, tensile, and compression stresses imposed are described. The types of support required from wood piles are discussed, as well as the effect of preservative treatment upon mechanical strength.

IN ESSENCE, THE FUNCTION of a pile is merely to transmit a superimposed load or loads to the adjacent soil, or to a hard underlying stratum such as rock.

Specifications for round timber piles are based on long experience in their use; experience accumulated during milleniums of unrecorded and recorded history. Caesar's legions bridged many a stream—large and small—on piles driven by heavy mauls or by crude rams. Many ancient structures were erected on pile foundations; ruins of some of these still exist.

These structures sufficed for the comparatively light loads which they bore. Progressively heavier loadings imposed by the storage of materials, heavy machinery, and by traffic of this age have necessitated the use of larger piles and much heavier and more efficient driving equipment.

To ensure procurement of round timber piles adequate for the service required, standard specifications for acceptance or rejection have been prepared by various bodies.

Current Specifications

Of the specifications current in Canada and the United States those authorized by Canadian Standards Association, American Society for Testing Materials, American Railway Engineering Association, American Standards Association, and American Society of Civil Engineers are the best known and the most used. All provide for three pile classifications—"A", "B", and "C". Classification "A" specifies minimum diameter, at three feet from the butt, of 14 inches to accommodate a 14-inch cap; "B" a minimum diameter, at three feet from the butt, of 12 inches to accommodate a 12-inch cap; and "C"—of poorer general quality than "A" or "B"—a minimum diameter, at three feet from the butt, of 12 inches. The maximum diameter at three feet from the butt for Class "A" piles varies with length for softwoods, except cedar, which remains constant at 22 inches; for hardwoods it remains constant at 18 inches. For Class "B" piles, softwoods, the maximum diameter, at three feet from the butt, is 20 inches for all lengths, except that for cedar 22 inches is specified. For hardwoods of this class 18 inches is specified for all lengths to 30 feet and 20 inches for all lengths greater than this. In some instances the limiting diameter will be the clearance between pile driver leads.

Specifications of the American Railway Engineering Association differ from the others for Class "C" piles. Maximum diameter, at three feet from the butt, is greater for all lengths. Minimum tip measurements are smaller for Douglas fir in 90-foot lengths and larger for cedar 40 feet and longer.

Variations Slight

Differences between the general requirements of the five specifications are slight. Canadian Standards Association and American Society for Testing Materials require that untreated piles used in exposed work shall show heartwood on the butt for not less than 80 percent of the diameter. Objection has been registered to this percentage because Douglas fir of pile dimensions does not normally show so much heartwood. A survey was made recently by the Forest Products Laboratory, Vancouver, during which 1,000 piles ranging from 20 to 120 feet in length were measured. Of these, only 307 measured 79.9 percent and more of heartwood diameter on the butt end, so that fewer than one in three would be acceptable for use untreated in exposed work on current specifications. The piles sampled were cut on the British Columbia mainland, the Gulf Islands, and on Vancouver Island, so that the percentage is fully representative.

It is of interest to note that the Canadian Standards Association specification for round timber piles is undergoing revision. It is anticipated that the 80 percent heartwood requirement will be reduced somewhat.

On the Pacific Coast the principal species cut and marketed for piles are: Douglas fir, western red cedar, and western hemlock; spruce and western larch are used to a limited extent. Douglas fir is predominant.

Piles must possess certain essential characteristics. Among these are freedom from sharp bends, knots of limited dimension, limited shakes, splits, decay, and crooks. It is desirable—although no specification requires it—

TABLE I

Safe Working Stresses for Timbers Graded as Structural in Accordance with C.S.A. Specifications for Structural Timber

Species	Bending p.s.i.	Ratio to Douglas fir	E Bending p.s.i.	Ratio to Douglas fir	Comp.	Ratio to Douglas Fir
Douglas fir	1,320	1	1,600,000	1	960	
Hemlock, western	1,140	7/8	1,400,000	7/8	800	13
Larch, western	1,320	1	1,500,000	15/16	960	
Spruce sp.	960	3/4	1,200,000	3/4	640	2
Pine red	960	3/4	1,200,000	3/4	640	
Pine sp.	780	5/8	1,000,000	2/3	640	2
Tamarack	1,050	13/16	1,300,000	13/16	800	1
Oak, red and white	1,230	15/16	1,500,000	15/16	880	1

[1] Contribution from the Vancouver Laboratory, Forest Products Laboratories Division, Forestry Branch, Dept. of Resources and Development, Canada.

[2] Presented at meeting of Forest Products Research Society, Pacific Northwest Section, October 28, 1952, at Vancouver, B. C.

Twenty-five foot Douglas fir pole in place for testing.

Same pole after fracture.

that there should be no large knot or knot whorls in the 10–15 foot section nearest the tip.

Trees are the source from which piles must be procured, and, from a structural use viewpoint, trees possess inherent defects. It is necessary, therefore, to select piles so that defects will be limited in number, dimensions, and location in accordance with current specifications. These have been based upon long experience and balanced judgment. Maximum and minimum diameters for different species and established classes, knot dimensions, and the permissible amount of splits, shakes, and decay are specified in all standards, as are minimum tip diameters.

The relative strength properties for eight species used as piles are shown in Table 1. These are based upon design stresses for structural grade material, Canadian Standards Association. Three species not occurring in British Columbia have been included for comparison.

Three types of support affect pile design:

(1) Column support: in which the full load is borne on the end of the pile, in which case the pile should be designed as a column; the ratio of its length to its diameter at one-third the length from the tip should never exceed 50. For this ratio the end load which can be supported safely will be reduced to 15 percent of that for a short column, and specification limitations for defects are far too severe, as the governing factor will be modulus of elasticity which varies but little with grade quality if the wood is sound.

(2 Skin friction support: in which the entire load borne by a pile is transmitted to the adjacent soil by friction alone—its limiting value being sheer of the soil. This type is tricky as there are so many factors involved. A few of these are: whether the pile is driven into undisturbed or filled ground and, if into filled ground, whether settlement has stopped; the character of the soil—glacial, alluvial or residual; the characteristics of the various strata which the pile must penetrate; the water content of the soil; whether hard strata overlie soft strata in the length of the pile, or vice versa; whether the strata are at rest or if some are moving laterally; and whether the load to be borne will be static without vibration or if vibration will occur. This last may result from the operation of heavy machinery such as generators, motors, turbines, printing presses, steam or pneumatic hammers, reciprocating engines, and gang saws.

If the vibration period induced by any of these machines is akin to the natural frequency of vibration of soil and pile combined, the rate and amount of ultimate settlement is apt to be accelerated considerably and to be increased greatly, and this may occur even to disastrous proportions.

(3) End bearing combined with skin friction support.

There exists the further factor of the supporting power of groups of piles as compared with that of a single pile. The over-all number of piles in an area, their arrangement and spacing all have significant effects.

Piles support two general types of loads, namely, static and impact. These may be subdivided again into sub classes as follows:

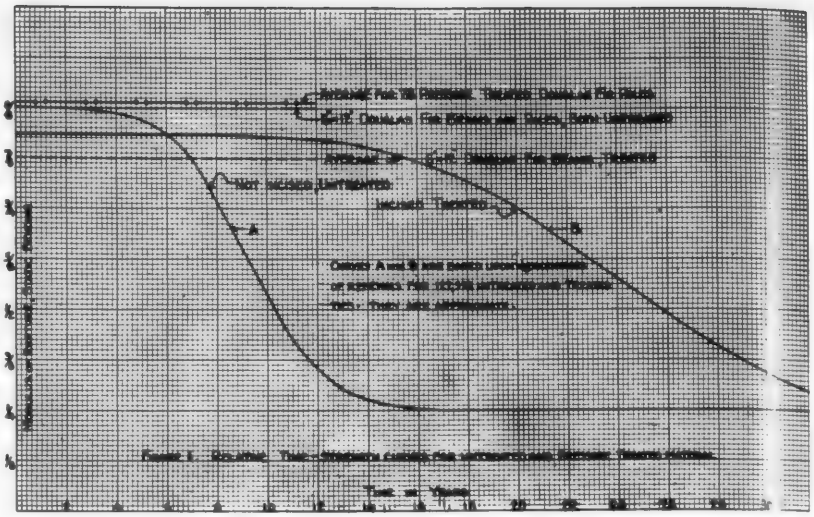
1. Impact during driving. If possible, driving should be done with a heavy ram using a short stroke in order to avoid high velocity at the instant of impact. This is probably the greatest factor in brooming, splintering, and splitting piles. It should be noted that a drop of 25 feet results in two and one-half times the velocity of a drop of 4 feet.
2. Impact in service. This may be the result of logs, floating objects or ships being slapped against a structure by wind or wave action or by both combined; of a ship coming into moorings at too great speed; of an error in judgment resulting in a ship ramming a dock; or of a rapidly moving load passing over a structure supported on pile foundations.
3. Static stresses. These include bending, tensile, or compressive stresses or combinations of them; they include: (a) bending stresses during handling and placing; (b) bending stresses due to lateral forces; (c) bending stresses due to eccentricity of loading; (d) bending stresses due to curvature in the pile itself; (e) tensile stresses due to uplift and rebound; (f) compressive stresses due to service loading.

Lateral forces may be exerted in many ways. They can occur through pressure of floating objects such as ships, barges, and log rafts; by wind action forcing ships laterally against wharves and docks (short of impact); or wind action on wharf and dock structures. They result from snubbing

and warping ships into moorings, and through friction drag by reason of wind, tide or current, if the ship lies parallel to the current, as well as through propeller drag if the propellers are large. Wind action on trains crossing trestles or bridges, and centrifugal forces owing to high speed of trains crossing curved bridges or trestles, also exert lateral forces.

In pile design five factors must be considered in addition to the character and the amount of the superimposed load. These are:

1. Lateral support.
2. End conditions—degree of fixity top and bottom.
3. Unsupported length.
4. Local building codes.
5. Terms of contract.



Finally there arises the question of the effect of pressure treatment upon the mechanical strength of piles. Tests in the laboratories of the Forest Products Laboratories Division showed that sawed timbers of Douglas fir, treated by boiling in vacuum by current methods specified by the American Wood Preservers Association, suffered a probable average reduction in strength—due to the combined factors of incising and pressure treatment—of one-eighth. This reduction is not serious when consideration is given to the great range in strength which occurs in any established structural grade, and, the same design stresses are used for untreated and treated timbers of equivalent grade of any species.

A series of static bending tests of 56 Douglas fir poles, 25 feet long, (28 each untreated and treated), made in the Forest Products Laboratory, Vancouver, in 1930–33 showed an average difference of 213 p.s.i. in modulus of rupture of the two groups, the difference being in favor of the treated poles. This is an insignificant difference. A project, still incomplete, in which 100 Douglas fir poles cut at an elevation of approximately 3,500 feet near Merritt, B. C. have been tested, one-half the number untreated and the remainder after pressure treatment, has shown an average difference of 110 p.s.i. in modulus of rupture for the two conditions. The results needed no adjustment for variation in moisture content because all poles had stood upright in a tank of water with the water level at the ground line of the poles for weeks prior to testing, thus assuring that the wood was in green condition at the section of fracture when the tests were made.

Effect on Strength

It is safe to anticipate that round timbers, whether poles or piles, pressure treated to the current specifications of the American Wood Preservers Association, do not change significantly in bending strength by reason of the pressure treatment.

For any structure supported on pile foundations it must be borne in mind that although a comparatively small uniform settlement over the whole area may not be cause for alarm, a differential settlement may be as disastrous as a destructive earthquake. Therefore, no hard and fast rule can be laid down for loading, impact or static, or high short-time overloads, without a good knowledge of local conditions and geological formations underlying the site. In addition there should be loading tests of piles driven in the foundation area, and the piles pulled if necessary to determine the effect of the driving upon their integrity.

Note: Illustrations, photographs and Figure 1 have been taken from tests of poles made at the laboratory and are used as illustrations only. Pile test procedure would be similar.

HOW TO TELL BIRCH, BEECH, AND MAPLE APART

Birch, beech, and maple are very similar in appearance, and have approximately the same weight. Hence, it is comparatively easy to mistake one of them for another. A method which anyone can use to distinguish them is suggested by the U. S. Forest Products Laboratory. The method makes use of the relative size of the pores and rays in the three woods.

If the end grain of birch, beech, or maple is cut smooth with a sharp knife and examined with a hand lens, the pores will be seen as tiny holes distributed fairly evenly over the surface, and the rays will appear as narrow lines of a different shade running at right angles to the growth rings. In beech some of the rays are very distinct even without a lens. The large rays are fully twice as wide as the largest pores. In maple the rays are less distinct, and the largest are about the same width as the largest pores.

In birch the rays are very fine, invisible without a lens. The pores are several times larger than the rays, usually being visible to the unaided eye as minute holes on the end grain and as fine grooves on dressed faces of a board. The pores in birch are considerably larger than the pores in beech or maple.

The appearance of the rays on a "quartered" surface is also distinctive. Here they appear in beech as distinct "flakes," the largest being between 1/4 and 1/8 inch in height when measured along the grain of the wood. In maple they are considerably smaller, rarely attaining a height of 1/16 inch. In birch they are comparatively inconspicuous. . . . from U. S. Forest Products Laboratory.

Some Experiences with Treated Piling[1]

J. M. GURD
Vice-President, Timber Preservers' Ltd., New Westminster, B. C.

Describes briefly general specification requirements for piling as such and for treating same. Also describes effect creosoting has on pile driving, increased life to be expected, ultimate economy of treated piling, and effect of fire on creosoted material.

DOUGLAS-FIR PILING from the Pacific Coast usually is purchased by the wood preserving company on its own specifications. Such specifications in general conform to national standards such as those of the Canadian or American Standards Associations though they may vary in the top and butt dimensions to suit local needs. No sapwood thickness requirement is specified for piling that are to be used untreated. Piling to be pressure treated with a preservative are required to have a minimum of ¾ inch of sapwood (some specifications may require 1 inch of sapwood) for the treatment is limited largely to the sapwood.

The raw piling may be either hand or machine peeled to remove the bark and to trim the knots. Machine peeling appears to benefit the treating process; it tends to reduce the severity of checking, to permit more rapid seasoning, and to produce a deeper and more uniform treatment.

Seasoning

Piling may be air seasoned prior to treatment or it may be artificially seasoned as part of the treating process. This artificial seasoning process, known as Boultonizing, consists of heating the material in the preservative under a vacuum. When green or partially seasoned material is Boultonized, sufficient water must be removed to permit thorough treatment of the sapwood and the development of the natural checking pattern before application of the preservative.

Reasonable care must be exercised in handling and placing treated piling so as to prevent unnecessary cuts or breaks in the treated zone. Cut-offs and holes bored through treated wood should be field treated as specified in the American Wood Preserver's Association Manual of Recommended Practices.

Although a variety of preservatives may be used, this discussion will be limited to those recommended by the American Wood Preserver's Association, namely creosote, creosote-coal tar and creosote-petroleum. All must be applied by pressure processes.

Creosote is the only preservative recommended for piling to be used in coastal waters where marine borer attack can be expected. A minimum net retention of 12 pounds of creosote per cubic foot of wood applied by a full cell process is required. All three preservatives are recommended for general use with retentions of 8 to 10 pounds per cubic foot of wood.

Effect of Creosoting on Pile Driving

It is occasionally claimed by a pile-driving contractor that creosote or the result of creosoting tends to make piling brittle or "brashy". It is the writer's belief both from personal knowledge of pile-driving and from the results of a questionnaire to most of the companies engaged in that business in this area, that the statement is unfounded. Assuming that the material has been adequately and properly treated and in accordance with A.W.P.A. Specifications, there should be no more difference in the strength values than would normally exist between green and dry material. Since the outer portion of the piling has been dried to receive treatment, it may be that such material would be somewhat more brittle than wet material. It is recommended that treated piles be protected from splitting with a strong wire mesh on the butt and be driven with a steam-hammer. A wide survey of users of creosoted piling indicated that, when reasonable care is exercised in treating, handling and driving, no material differences exist between treated and untreated material.

Increased Life

Piling used in salt water frequently are subject to intensive attack from marine borers. Untreated piling will last but a few months or years, whereas properly preserved piling will last almost indefinitely. Many wharves and other structures erected on treated piling are still in good service after 50 years. The Southern Pacific Railway Wharf at Santa Monica, California is in good condition after 58 years. Another pier constructed at Oakland, California is now 47 years old. After 40 years service, only 2 percent of the piling under the Fisher Flouring Mills are in poor condition. Untreated piling in these same areas would have been destroyed within 3 to 10 years.

Considerable differences of opinion do exist as to the benefits to be derived from treating piling for fresh water use. Since deterioration does occur in such piling above the water line, it is recommended that important piling and those supporting structures be preservatively treated.

When piling is to be used on land, full consideration should be given to the value of the supported structure and to the severity of insect or fungal attack. Creosote or creosote solutions applied by an empty-cell process to net retention of 8 to 10 pounds should be specified for such use.

Foundation piling is the subject of much discussion. A foundation pile is one which is entirely embedded in the ground and capped with masonry. The two basic factors to be considered are economy and permanence. Because of the critical nature of such piling, a 12 pound retention is recommended. Since there is virtually no loss of preservative from a properly treated foundation pile, such piling, when properly capped, are permanent. Many railways, including the Atchison, Topeka and Santa Fe; Illinois Central; and Southern Pacific have records showing that treated material placed 50 years ago is still sound. An inspec-

(Continued on page 90)

Economics involved in the Use of Treated Piling

Basis—50′ Piling	Green	Treated
Cost in place	$52.50	$90.00
Estimated Life	10 years	50 years
Interest Rate	5%	5%
Annual Charge Factor	.1295	.0548
Annual Charge per Pile	$ 6.80	$ 4.93
Annual Saving per Pile		$ 1.87
Saving per Pile over 50 year life		$93.50

[1] Presented at meeting of the Forest Products Research Society, Pacific Northwest Section, October 8, 1952, at Vancouver, B. C.

Effect of Specimen Size and Shape on Percentage Water Absorption in Ten Different Types of Commercial Hardwoods[1,2]

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In Charge Timber Mechanics and

J. W. JOHNSON
Wood Technologist, Oregon Forest Products Laboratory, Corvallis, Ore.

Ten different types of commercial hardboards were tested for the effect of test specimen size and shape upon percentage water absorption in a 24-hour water absorption test. The sizes and shapes included within the scope of the study were: 12- by 12-inch, 6- by 6-inch, 3- by 3-inch, 4- by 9-inch and two sets of 3- by 12-inch. The latter two sets were included to study possible directional properties. In all, 1800 observations were made.

The final conclusion ensuing from the analysis of the test results is that any specimen size having a surface area of 72 square inches (face plus back) between the limits 3- by 12-inch and 6- by 6-inch could be used on both treated and untreated hardboards in nominal thicknesses of ⅛ and ¼-inch. In most cases it is not necessary to consider machine direction when a shape other than a square is used.

The test results suggest the advisability of considering changing the present tentative A.S.T.M. standard (D 1037—52T) covering the water absorption test.

Introduction

THIS INVESTIGATION IS PART of a larger research effort at the Oregon Forest Products Laboratory to assist in arriving at universally accepted test procedures for commercial hardboards. The coordinating committee of the hardboard division, Pacific Northwest Section of the Forest Products Research Society had cognizance of the work.

Definitions

Certain descriptive words which may cause confusion will be used in this paper. It seems propitious at this time to define these terms.

Class: two classes of hardboard are included (treated and untreated)

Type: comprises hardboard of one thickness, one class, and from one producer

Board or sheet: a 4- by 4-foot piece of hardboard

Test specimen: comparatively small pieces of hardboard of different sizes cut from a board or sheet

The effect of specimen size and shape upon percentage water absorption in commercial hardboards was not known with any degree of certainty for several types of hardboard. Practical considerations make a small specimen size advantageous although a large specimen size may give lower and therefore more desired water absorption values. Most of the past work on this specific problem has been limited to one or two types of hardboard, and the sampling procedure has been open to question in most tests. Previous work indicated that specimen size does influence the percentage water absorption values for a given board; but it was not known whether the relationships found for these boards would hold for all types of commercial hardboards. If this property is similar to some other physical properties of hardboards, the relationships will be different for the several types of boards.

Objectives: The primary objective of this experiment was to determine the effect of specimen size and shape upon percentage water absorption for ten different types of commercial hardboards from four different producers. A secondary objective was to evaluate the possible effect of the board's directional properties upon water absorption for one size and shape of test specimen.

Experimental Procedure

Scope: Treated and untreated boards in ⅛- and ¼-inch thicknesses were included within the scope of the experiment. No. S2S Boards were included in the study. The following specimen sizes and shapes were used in the investigation: 12- by 12-inch, 6- by 6-inch, 3- by 3-inch, 4- by 9-inch, and two sets of 3- by 12-inch specimens, one parallel and one perpendicular to the machine direction of the board.

Design: For each of the ten types of commercial hardboards, five 4- by 4-foot sheets were selected at random. Each sheet was cut into test specimens as illustrated in Figure 1. Such an experimental design should accomplish two purposes: (1) give a sufficient number of test observations for any specimen size and shape to yield a confident estimate of the average percentage water absorption and (2) eliminate the possible disturbing effect of differences in average specific gravity among comparison groups. From each sheet, six test specimens were cut for each size and shape group, a total of 30 observations per hardboard type. Since there were six different groups of test specimens, the total number of observations in the study was $6 \times 30 \times 10$ or 1800.

Testing Procedure: Ordinary tap water with a ph of $7.4 \pm .2$ was run into large pans which were placed in a temperature-humidity-controlled room. The water was left in the pans until an equilibrium temperature be-

[1] A Research Project in the Timber Mechanics Section, Oregon Forest Products Laboratory, Corvallis, Oregon.

[2] A progress report was presented before the Hardboard Division of the Pacific Northwest Section of Forest Products Research Society October 27, 1952, Vancouver, B. C.

tween 67 and 69° F. was reached. The 4- by 4-foot test sheets had been brought to an equilibrium moisture content by storing in a heated building for a period of one month under average inside temperature and humidity conditions. After the test specimens were cut for any type of board, they were weighed and submerged in the water pans with one inch of water above the top surface of the specimens (Fig. 3). Small-diameter brass welding rods were placed under and on top of the specimens. Because of the large number of specimens, it was necessary to place 10 in the water every 10 minutes. This procedure permitted ample time for weighing after soaking and ensured a 24-hour soaking period for all specimens. After soaking, and prior to weighing, the specimens were placed on racks to drain for 10 minutes, and the excess surface water removed with paper towels.

Percentage water absorption was calculated by taking the difference between the initial and final weight as a percentage of the initial weight.

Figure 2 illustrates graphically the relationship of surface area (face plus back) and percentage water absorption in commercial hardboards. The boards for company C were omitted in drawing the curves since they were not representative of the company's product and would tend to distort the average picture for the different classes of boards. It is clear by looking at the curves that percentage water absorption in the treated boards was much less influenced by differences in surface area than in untreated boards. Furthermore, a unit change in surface area below approximately 120 square inches reflected a greater change in water absorption in the ¼-inch than in the ⅛-inch boards for both treated and untreated material.

The curvilinear relationship of the surface area vs. percentage water absorption vividly points out the edge effect in this type of test. The ratio of edge area to surface area increased from 1:12 for the 3- by 3-inch specimens to 1:48 for the 12- by 12-inch specimens in the ⅛-inch material. As this ratio increased, the percentage water absorption decreased. Obviously, this relationship was not proportional since it was not linear. The change in percentage water absorption for a unit change in the ratio decreased as surface area increased.

The heavy solid line represents the average values for all boards tested with the exception of company C's boards. This may not be a representative picture since only one company's treated board was represented for each

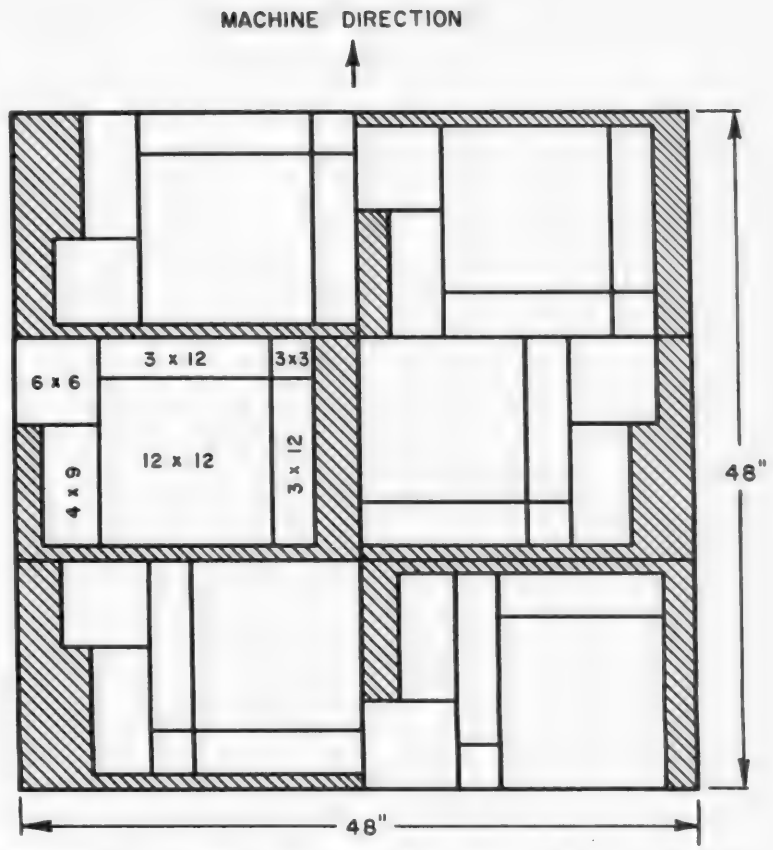


FIGURE 1.— CUTTING PLAN FOR EACH 4 FT. BY 4 FT. TEST SECTION.

Table 1. Average Percentage Water Absorption for Different Sizes and Shapes of Test Specimens in Ten Types of Commercial Hardboards

	Hardboard description				Test specimen size in inches					
Type no.	Producer	Thickness (in.)	a Class	b L.S.D.	12x12	6x6	3x3	4x9	c 3x12	d 3x12
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	A	1/8	UT	.71	14.79	14.59	16.08	14.91	14.78	15.03
3	B	1/8	UT	.77	14.43	15.27	17.83	15.47	15.53	16.33
5	C	1/8	UT	1.44	24.00	25.84	28.95	27.63	26.64	25.72
7	D	1/8	UT	.67	10.91	14.11	15.54	14.49	12.47	12.12
2	A	1/4	UT	.72	9.69	11.72	15.60	11.94	11.82	13.02
4	B	1/4	UT	.60	10.92	12.18	14.20	13.35	12.77	12.45
6	C	1/4	UT	.93	16.84	19.74	19.07	17.87	19.87	19.68
8	D	1/4	UT	.80	8.66	9.65	11.15	10.62	10.80	10.68
9	D	1/8	T	.41	7.48	7.60	7.82	7.71	8.67	7.67
10	D	1/4	T	.11	2.48	2.53	3.10	2.45	2.63	2.64
	Averages	Both	All	.77	12.02	13.32	14.93	13.64	13.60	13.53

a. UT Untreated
T Treated
b. Least significant difference
c. Longitudinal axis oriented perpendicular to the machine direction.
d. Longitudinal axis oriented parallel to the machine direction.

thickness. A weighted average was not used since it was not known for certain that company D's treated board was typical of all commercial treated boards.

Table 1 summarizes average percentage water absorption for five different size-shape groups. One of these groups with the same size and shape but different orientation with respect to machine direction was repeated, giving a total of six comparison groups. All test data have been analyzed by the method of analysis of variance. For the benefit of those who may be particularly interested in this type of analysis, the summary details are included in the statistical analysis at the end of the report.[a] The least significant difference factor in the fifth column of Table 1 is the difference that any two averages must exhibit before one average can be interpreted as significantly higher or lower than the other. With this yardstick in mind, the following significant relationships were found.

A. Specimens of the same shape (square) but differing surface and edge areas (12- by 12-inch, 6- by 6-inch and 3- by 3-inch)

1. In seven of eight cases, the percentage water absorption in 1/8- and 1/4-inch untreated boards for the 6- by 6-inch specimens was significantly higher than the 12- by 12-inch specimens. In the same number of cases, the 3- by 3-inch size was higher in absorption than the 6- by 6-inch size.

2. No difference was observed in 12- by 12-inch and 6- by 6-inch specimens in 1/8- and 1/4-inch treated boards. No difference was found between the 6- by 6-inch and 3- by 3-inch size in the 1/8-inch treated board, but the 3- by 3-inch size was significantly higher in percentage water absorption in the 1/4-inch treated board.

B. Specimens with the same surface area but different shapes (6- by 6-inch, 4- by 9-inch and 3- by 12-inch)

1. There was no consistent pattern among the ten types of hardboards when specimens of the same surface area were compared (columns 7, 9, 10, and 11 in Table 1). When all ten types were pooled (last line in Table 1) there was no significant difference among size-shape groups with the same surface area.

C. Directional differences for the 3- by 12-inch test specimen size.

1. In three of ten cases there was a difference found in water absorption for specimens which have their longitudinal axes oriented at right angles to each other. The difference among the three types was not consistent.

D. The following general statements can be made for different group comparisons (Table 4):

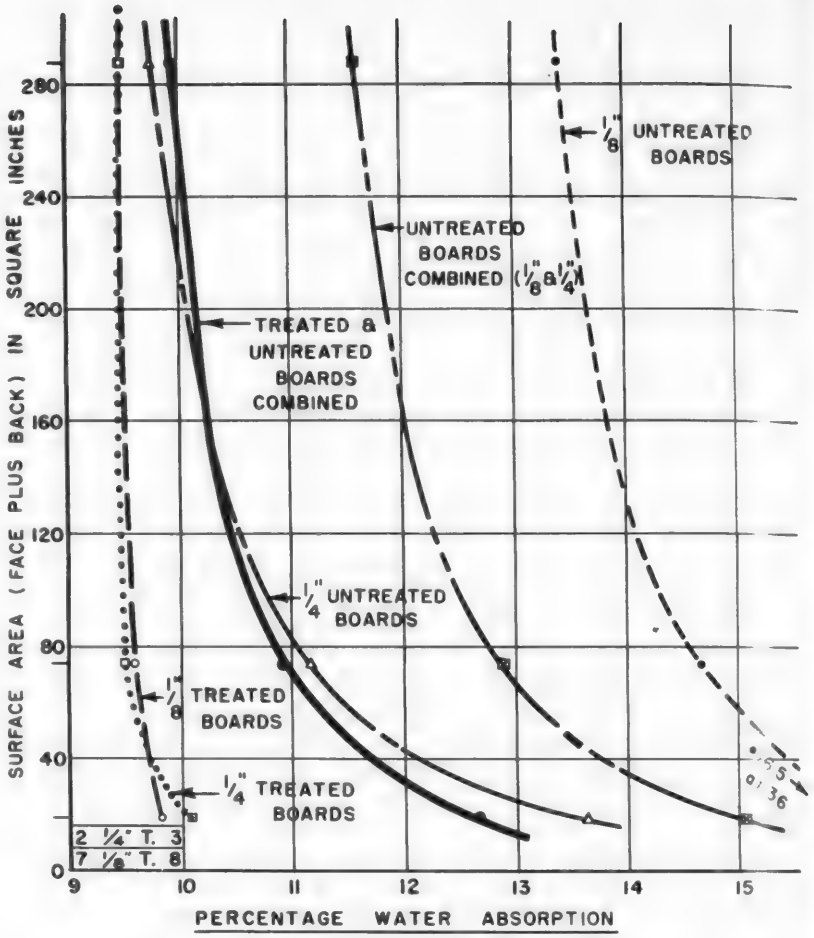


FIGURE 2 — RELATIONSHIP OF SURFACE AREA AND PERCENTAGE WATER ABSORPTION IN COMMERCIAL HARDBOARDS.

Table 2. Analysis of Variance for the Ten Boards Combined

Variation due to:	Sum of squares	Degrees of freedom	Mean square	F	Remark
Types	66,157.19	9	7,350.80	41.93	sig.
Boards (within) type	7,012.01	40	175.30	----	
Test	1,286.44	5	257.29	106.44	sig.
Test x Type	993.81	45	22.08	9.14	"
Test x Board	227.78	200	1.14	.47	
Within Tests	3,625.88	1500	2.42	----	
Total	79,303.12	1799			

[a] The authors would like to express their appreciation to Dr. Jerome C. R. Li, Mathematics Department, Oregon State College for his assistance in the statistical work.

Figure 3.—A water pan showing test specimens submerged with one inch of water above the top surface.

1. One-eighth-inch boards had higher water absorption values than the ¼-inch boards in both treated and untreated material.
2. All treated boards exhibited lower percentage water absorption than untreated.
3. There were significant differences among the four producers within each thickness group.
   a. The company C boards in both thicknesses had significantly higher percentage water absorption averages than corresponding boards from the other three companies. This should not be construed as an expected situation, since company C was in the process of major plant changes at the time the test material was collected. The differences in values among the producers were not too important since the primary objective of this investigation was to compare test specimen sizes.

At the present time, there is no reasonable explanation for the anomalous relationships that were summarized in Table 1. It is not too surprising, however, to find such a condition when differences in raw material and process variables are considered. There is also a slight possibility that the average specific gravity values for different comparison groups were not alike. This is possible since the assignment of test specimens was not made in a truly random manner, although the number of test specimens for each comparison group was comparatively large, namely, 30.

Despite the cases which deviated from a general pattern, it would appear that definite recommendations can be made from the test results. If it can be assumed that the objective in any standard testing procedure is to find a set of conditions which will satisfactorily evaluate the majority of the material to be tested, the following recommendation can then be made for the 24-hour water absorption test of hardboards (refer to average figures in last line of Table 1).

In treated and untreated hardboards with a nominal thickness between ⅛- and ¼-inch, a specimen having a surface area of 72 square inches (total area of face and back) between the dimensional limits of 3- by 12-inch and 6- by 6-inch could be used.

It should be remembered, of course, that the selection of any specific test specimen size is purely arbitrary. Even though significant differences in average water absorption are found for different test specimen sizes, the acceptance level of water absorption must be decided. For example, any square specimen might be used if the difference in magnitude of the average values for different squares is not considered to be of practical importance; however, it should be clear from the results of this study that the dimension of the square must be specified. This research effort has furnished enough evidence to suggest the advisability of revising the current tentative A.S.T.M. standard (D 1037-52T) which permits the use of either a 12- by 12-inch or a 6- by 6-inch specimen size.

Table 3. Summary of Analysis of Variance for the Ten Types of Commercial Hardboard

Variation due to:	Degrees of freedom	Significance by type of board (column 1, table 1)[a]									
		1	2	3	4	5	6	7	8	9	10
Board	4	S	S	S	S	S	S	S	S	S	S
Test	5	S	S	S	S	S	S	S	S	S	S
Board x Test	20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Test (7) (9) (10) (11) (Table 1)	3	NS	S	S	S	S	S	S	S	S	S

[a] S Significant difference at 0.95 probability level
NS No significant difference

Table 4. Analysis of Variance for Different Group Comparisons Involving Thickness and Type

Variation due to:	Sum of squares	Degrees of freedom	Mean square	F	Remarks
1/8" vs. 1/4"	6,171.50	1	6,171.50	35.21	sig.
Among 1/8"	19,300.04	3	6,433.35	36.70	"
Among 1/4"	7,435.97	3	2,478.66	14.14	"
9 vs. 10[a]	2,457.58	1	2,457.58	14.02	"
9 and 10 vs. rest	30,792.11	1	30,792.11	175.65	"
Boards (within type)	7,012.01	40	175.30	-----	

[a] Numbers refer to specific type as described in Table 1.

Statistical Analysis

The following statistical data are included for those who are interested in this comparatively new type of analysis for wood and wood-base products. Detailed calculation data are not included since the techniques can be found in any statistical reference; only the summary analyses of variance tables are included.

The first step in the analysis was to combine all test data for the ten types of commercial hardboards in an analysis of variance to determine if significant interactions existed. This is summarized in Table 2.

The most important observation from this analysis of variance is the interaction test vs. type was significant. This suggested the wisdom of analyzing each type of board separately. Table 3 summarizes the analysis of variance data by type of board.

Table 4 is included to substantiate the statements made concerning different comparison groups dealing with thickness and treatment of boards.

Effect of Head Speed and Span on Modulus of Rupture in Several Types of Commercial Hardboards[1,2]

J. R. STILLINGER[3]

In Charge, Timber Mechanics, Oregon Forest Products Laboratory, Corvallis, Ore.

Thirteen types of hardboard representing four producers, four sources of raw material, three basically different processes, two thicknesses, and two classes (treated and untreated) were included in the sampling plan to investigate the relationship of head speed, span, and modulus of rupture in the testing of commercial hardboards.

Eight head speeds ranging from 0.05 to 4.00 inches per minute were employed in testing material over 4- and 8-inch spans. As a check on previous work, a supplementary experiment included testing one type of board on the 2-, 3-, and 6-inch spans for part of the range of head speeds.

The analysis of test data showed that for each type of board tested there was a range of head speeds from 0.50 to 2.00 inches per minute that did not yield significantly different modulus of rupture values. The test results further indicated that there was a rate of fiber strain which was critical, although not accurately determined, and which, when reached, produced very definite decreases in modulus of rupture values.

Introduction

THE HARDBOARD INDUSTRY and different hardboard consumers have been handicapped by the lack of a universally acceptable test procedure for a static bending test. The difficulty in arriving at a standard procedure has been due primarily to the lack of reliable information on the effects of head speed and span on the modulus of rupture for the products being evaluated.

Definitions

Throughout this paper certain descriptive words will be used that may cause some confusion. Therefore, it seems wise to define these first.

Class: there are two classes of hardboard, untreated and treated

Type: comprises hardboard of one thickness, one class, and from one producer

Board or sheet: a 4- by 4-foot or 4- by 8-foot piece of hardboard

Test specimen: comparatively small pieces of hardboard of different sizes cut from a board or sheet

Review of Previous Work: Investigation of previous work on the relationship of head speed, span, and modulus of rupture in commercial hardboards left little doubt of the need for a more comprehensive study of the two variables, head speed and span. Generally speaking, the past work of particular research organizations or industry groups has been limited to a study of the products of an individual company. Consequently, the relationships are not known for many different classes and thicknesses in several manufacturers' products.

The U. S. Forest Products Laboratory at Madison, Wisconsin, realized the need for information on the relationships of head speed, span, and flexural properties in commercial hardboard (6). This work dealt with a range of head speeds from 0.06 to 4.00 inches per minute for test specimens from one manufacturer tested over 6- and 8-inch spans. One thickness and one class of board were included in the scope of the work but only three test specimens were used for any combination of variables. This small number of test observations for such a variable material as hardboard definitely reduces the confidence that can be placed in the average property values.

Wilcox (4) reported on a comprehensive study of head speed, span, and modulus of rupture relationships in a nominal $\frac{5}{32}$-inch Douglas-fir hardboard produced at the Oregon Forest Products Laboratory, Corvallis, Oregon. Spans of 2, 3, 4, 6, and 8 inches and head speeds of 0.06, 0.60, 1.0, 2.0, 4.0 and 6.0 inches per minute, a total of 30 combinations, were used in his study. Ten test observations were used for each combination. This work adequately evaluated the relationships for the one type of board. The method (3) used to adjust specific gravity values to a common base is open to question (4). Recent work at the Oregon Forest Products Laboratory indicated that the relationship of modulus of rupture and specific gravity in commercial hardboards is not the same for all types of boards and, furthermore, varies considerably among boards within one class, one thickness, and one producer. This inconsistency suggests the advisability of using a completely random selection of test specimens for different comparison groups so the differences in specific gravity will average out. A correction for specific gravity should be made only when a reliable factor is available for each board from which test specimens are selected. This is not often possible because of the comparatively small number of specimens usually taken from a given board.

A careful review of commercial and federal specifications and the A.S.T.M. tentative standard (D 1037-52T) showed a lack of agreement on recommended head speed and span to use in evaluating the flexural properties

Figure 1.—Baldwin-Tate-Emery-Air-Cell weighing system attached to the movable cross-head of a 20,000 lb. electo-mechanical Tinius Olsen testing machine.

[1] A Research Project in the Timber Mechanics Section, Oregon Forest Products Laboratory, Corvallis, Oregon.

[2] A progress report was presented before the Hardboard Division of the Pacific Northwest Section of the Forest Products Research Society October 27, 1952, Vancouver, British Columbia.

[3] The author wishes to acknowledge the assistance of J. W. Johnson, Wood Technologist, Oregon Forest Products Laboratory, in making the physical tests and statistical calculations.

of commercial hardboards (1). This lack of agreement, and the lack of previous work covering the broad scope of current commercial hardboards prompted the Oregon Forest Products Laboratory to instigate this investigation.

The primary objective of this research project was to determine the relationship of head speed and modulus of rupture for 4- and 8-inch spans in several types of commercial hardboards. It was assumed that the ultimate goal is a universally acceptable test procedure for determining the flexural properties of commercial hardboards; for this reason the sampling included a broad range of thicknesses, classes, and producers of commercial hardboards.

When making a final selection of particular head speeds and spans to use in the static bending test the following questions should be considered: (a) is the head speed practical from the standpoint of efficient use of time in carrying out the test? (b) will the test procedure give modulus of rupture values that are least influenced by small deviations in testing variables? (c) is the modulus of rupture value resulting from the recommended test procedure within the consumer-acceptance limits that have been established from prior selling experience? (d) does the procedure make possible direct comparisons of test data among producers, research organizations, and testing agencies, that are using different types of testing equipment?

Scope: It did not seem necessary to sample all types of commercial hardboards currently available, but rather to be sure that a wide variety of processes, raw materials, thicknesses, and classes were represented in the sampling plan. Four producers, four sources of raw material, three basically different processes, two thicknesses, and two classes (treated and untreated) were represented in the final sampling plan. No S2S boards were included in this study.

Eight head speeds (0.05, 0.15, .25, .50, .75, 1.00, 2.00, and 4.00 inches per minute) were used on material tested over the 4- and 8-inch spans. As a check on previous work, one type of board was tested over 2-, 3-, and 6-inch spans for part of the range of head speeds.

Experimental Procedure

The experimental work was divided into two major subdivisions, 8- and 4-inch spans. The analysis of the components of variation in the first part of the study enabled a more efficient experimental design in the second phase of the work.

Table 1. AVERAGE SPECIFIC GRAVITY FOR THE SEVEN TEST SPECIMENS SELECTED FROM EACH TEST SHEET, BY HEAD SPEED AND BOARD TYPE

Board type	Test sheet no.	Head speed (inches per minute) 0.05	0.15	0.25	0.50	0.75	1.00	2.00	4.00	Sig.[a]
1/8-inch untreated Company A	1	.988	.979	.971	.986	1.002	1.003	1.006	.998	S
	2	.995	1.001	1.002	1.008	1.004	1.003	.998	1.003	NS
1/8-inch untreated Company B	1	.933	.929	.935	.936	.908	.907	.926	.949	NS
	2	.920	.922	.937	.907	.933	.959	.941	.923	NS
1/4-inch untreated Company B	1	.939	.940	.937	.933	.933	.941	.936	.936	NS
	2	.938	.915	.920	.925	.935	.941	.912	.918	NS
1/4-inch untreated Company C	1	.839	.845	.837	.843	.846	.842	.844	.844	NS
	2	.873	.874	.882	.884	.867	.865	.867	.861	NS
1/8-inch treated Company C	1	1.036	1.041	1.043	1.048	1.039	1.059	1.050	1.053	NS
	2	1.051	1.051	1.049	1.048	1.047	1.063	1.045	1.062	NS

[a] S = Significant difference at 0.95 probability level
NS = No difference among head-speed groups

Table 2. AVERAGE PERCENTAGE MOISTURE CONTENT FOR THE SEVEN TEST SPECIMENS SELECTED FROM EACH TEST SHEET, BY SPEED AND BOARD TYPE

Board type	Test sheet no.	Head speed (inches per minute) 0.05	0.15	0.25	0.50	0.75	1.00	2.00	4.00	Sig.[a]
1/8-inch untreated Company A	1	3.9	3.8	3.6	3.9	3.9	4.1	3.7	3.7	NS
	2	3.8	3.9	3.8	3.5	3.6	3.7	4.0	3.5	NS
1/8-inch untreated Company B	1	4.4	4.1	4.9	4.8	4.8	5.2	4.3	5.0	NS
	2	4.5	4.7	4.6	4.2	4.7	4.7	4.4	4.8	NS
1/4-inch untreated Company B	1	4.8	5.1	5.1	5.1	5.2	4.9	5.3	5.1	NS
	2	4.9	5.3	5.2	5.0	4.5	4.8	5.0	5.2	NS
1/4-inch untreated Company C	1	5.9	5.5	5.3	5.0	4.7	5.3	4.9	5.1	S
	2	4.4	4.3	3.7	4.3	4.1	4.0	4.0	3.9	NS
1/8-inch treated Company C	1	3.2	3.4	3.1	2.6	3.1	2.9	2.5	3.2	S
	2	3.9	3.6	3.5	3.5	4.3	4.3	4.0	3.4	S

[a] S = Significant difference at 0.95 probability level
NS = No difference among head-speed groups

Experimental Design—8-inch Span: Test material from three producers was selected at random to be tested over the 8-inch span employing all the previously mentioned head speeds. Thicknesses of 1/8 and 1/4 inches in treated and untreated boards were represented in this phase of the study. In all, five distinctly different types of boards were tested. Two 4- by 4-foot sheets of each type of board were furnished by the respective producers. Each sheet was cut into 56 test specimens 3- by 11¾ inches. All test specimens were oriented so the line of failure was parallel to the machine direction of the board in order to reduce the total variation in test results. Previous work (6) indicated that the head-speed relationship would not be affected by different orientations of test specimens.

It was possible to include seven test specimens from each sheet for each of the eight head speeds, or a total of 14 observations from the two sheets of each board type. Test specimens were assigned to head-speed test-groups by thoroughly mixing the 56 specimens from each sheet and selecting at random one test specimen for each test group, then repeating the process until all test specimens had been assigned.

Experimental Design—4-inch Span: Statistical analysis of the test data for the 8-inch-span study suggested the wisdom of increasing the number of test sheets (4- by 4-foot) and decreasing the number of test specimens within a given sheet. This was apparent from the test results, which demonstrated that the variation between test sheets was much greater than within sheets. Therefore, the design was modified so five test sheets were used for each type of board and two test specimens were selected at random from each sheet, giving a total of 10 observations for any combination of variables. Based on the analysis of the data from the 8-inch-span test, the modified design should have given more confident average values. Eight different types of board were included in this phase of the study. Four of these types were the same as those used in the 8-inch-span study, and four were different. Thicknesses of 1/8 and 1/4 inches in treated and untreated materials were represented. Although the boards came from three producers, they were not the same three who supplied material for the 8-inch-span test; one new producer was added.

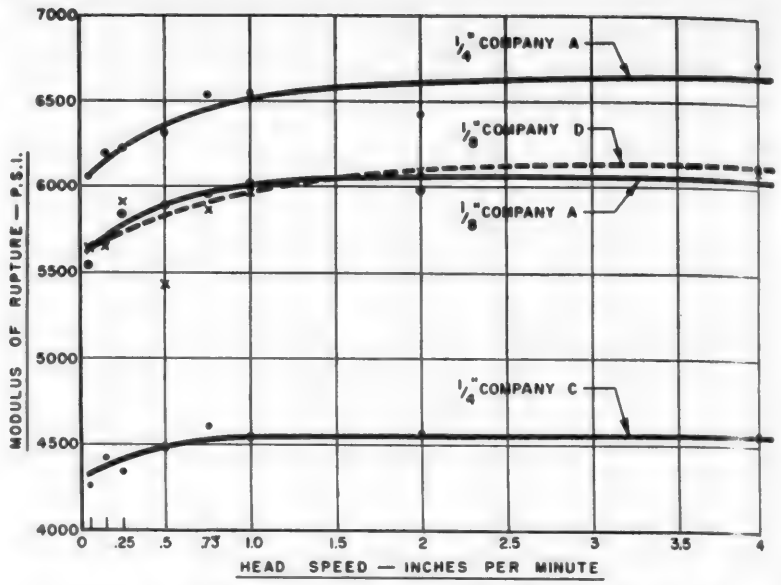
Test Procedure

Measurement Data: All test specimens were measured to the nearest 0.01-inch in width with a micrometer and to the nearest 0.001-inch in thickness with an Ames dial and plane table.

Conditioning: The test sheets were stored in a heated building with no temperature and humidity control for three months prior to testing; therefore, they should have reached a state of moisture equilibrium at time of test.

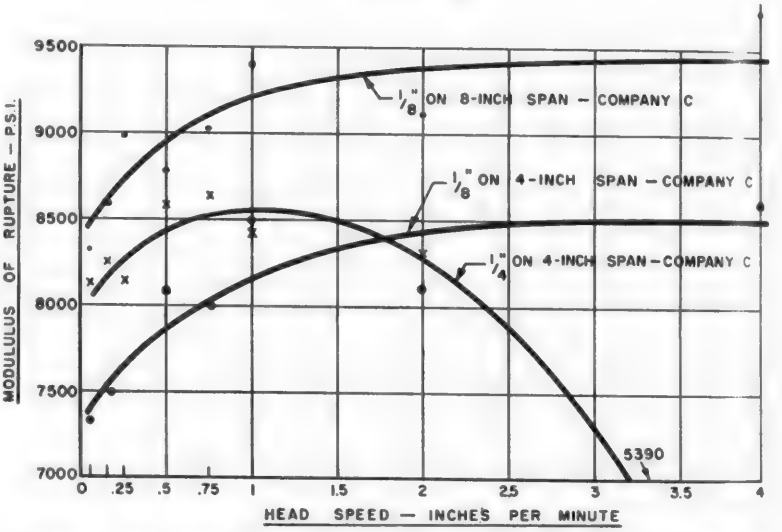
Physical Testing: A Baldwin-Tate-Emery-Air-Cell weighing system attached to the movable cross-head of an electro-mechanical Tinius Olsen testing machine of 20,000 lb. capacity was employed for applying and measuring loads (Fig. 1). The loads for all 1/4-inch untreated and treated and 1/8-inch treated test specimens were read to the nearest 0.5 pound; loads for the 1/8-inch untreated specimens were read to the nearest 0.1 pound. Center-point loading was used.

After the 8-inch-span test specimens were broken in bending, a 1- by 3-inch coupon was cut near the area of failure. The coupon was weighed immediately and the volume determined by the mercury-immersion method. The test coupons were placed in a drying oven and dried at a temperature of 100 ± 2° C. to constant weight. The initial and final weights and the volume at time of test furnished the necessary data to calculate moisture content at test and specific gravity based on oven-dry weight and volume at time of test. The principal reason for determining moisture content and specific gravity was to evaluate differences in average values among comparison groups. This was important since both specific gravity and moisture content affect modulus of rupture. The important consideration was to eliminate the influence of this possibly disturbing factor in order that the true effects of head speed and span could be evaluated.



EFFECT OF HEAD SPEED ON MODULUS OF RUPTURE IN UNTREATED HARDBOARDS TESTED OVER AN 8-INCH SPAN.

FIGURE 2



EFFECT OF HEAD SPEED ON MODULUS OF RUPTURE IN TREATED HARDBOARDS TESTED OVER A 4-INCH AND AN 8-INCH SPAN.

FIGURE 3

Results and Discussion

Check on Random Sample: Visual observation of the average specific gravity and moisture content values shown in Tables 1 and 2 reveals that the average sheet values for different head-speed groups within a given type of board were fairly close. A more accurate check for possible significant differences was made by using the technique of analysis of variance. The analysis showed that the groups of test specimens from nine out of ten test sheets showed no significant difference in moisture content. The

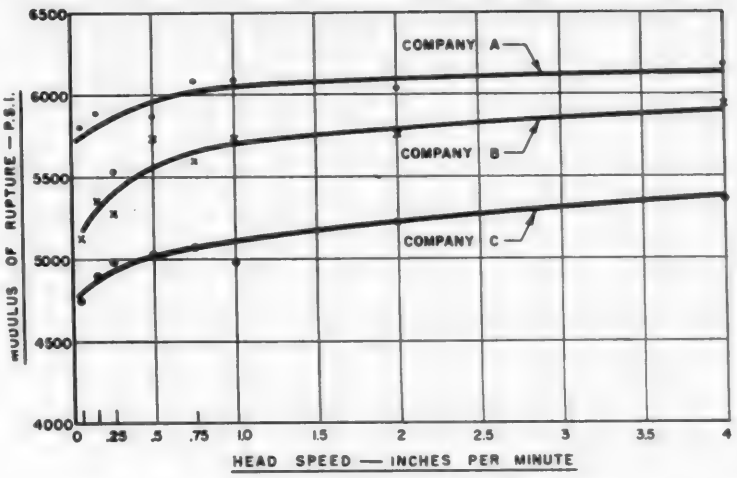
method of random selection did eliminate fairly well differences in specific gravity and moisture content among the comparison groups. Even though significant differences did occur, recent work at the Oregon Forest Products Laboratory indicates the magnitude of these differences was not enough to seriously affect the relationships among head-speed groups.

The selection of test specimens for the 4-inch-span study was improved over the method used for 8-inch-span study by using a table of random numbers in assigning test specimens. This method of selection assures a completely random assignment within a given sheet. It seemed advisable, however, to check this method of sampling on three widely different types of hardboard used in the 4-inch-span study. The analysis of the specific gravity data showed no significant difference in specific gravity among the head-speed groups for all three types of board. These results obviated taking specific gravity and moisture content determinations for the remainder of the 4-inch-span test material.

Effect of Head Speed on Modulus of Rupture: Figures 2 to 5 inclusive illustrate the relationship between head speed, span, and modulus of rupture for a range of head speeds from 0.05 to 4.00 inches per minute in several types of commercial hardboards tested over both 4-inch and 8-inch spans. Table 3 presents the same data and summarizes the statistical analysis. The least significant difference (last column of Table 3) is the yardstick by which averages for a given type of board must differ before a significant difference can be reported with a degree of confidence represented by the 0.95 probability level.

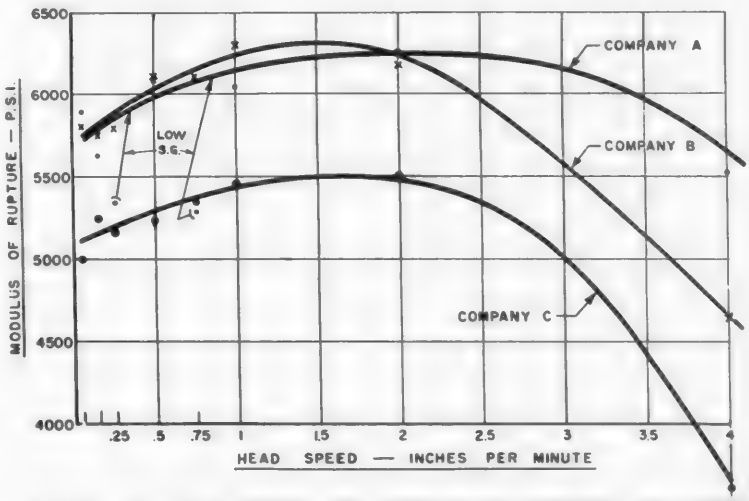
It is obvious from careful inspection of Tables 3, 5 and 6 that different types of commercial hardboard are not affected similarly by head-speed changes. Two of the types tested over an 8-inch span and two tested over a 4-inch span showed no significant difference in modulus of rupture over the entire range of head speeds used. Other types exhibited different patterns.

The curves for 1/8- and 1/4-inch material tested over an 8-inch span and the 1/8-inch material tested over a 4-inch span clearly exhibit a plateau area between the head speeds of 1.00 to 4.00 inches per minute. The statistical analysis of the data indicated that there was a zone of head speeds between 0.5 and 2.00 inches per minute which did not give significantly different modulus of rupture values within any type of board tested. This zone has been set off by heavy lines in Table 3. The zone actually can be extended to include 0.25 inches per minute for all except three types of the boards studied.



EFFECT OF HEAD SPEED ON MODULUS OF RUPTURE IN THREE 1/8-INCH UNTREATED HARDBOARDS TESTED OVER A 4-INCH SPAN.

FIGURE 4



EFFECT OF HEAD SPEED ON MODULUS OF RUPTURE IN THREE 1/4-INCH UNTREATED HARDBOARDS TESTED OVER A 4-INCH SPAN.

FIGURE 5

The 1/4-inch material tested over a 4-inch span exhibited a strikingly different relationship for the 4.00-inch-per-minute head-speed. All four types of 1/4-inch boards showed a pronounced decrease in modulus of rupture values when the head speed was increased from 2.00 to 4.00 inches per minute. This same phenomenon has been reported by Wilcox (5). His work included head speeds up to 6.00 inches per minute and spans as low as 4 inches for 1/4-inch, and 2 inches for 1/8-inch commercial hardboard. The 2- and 3-inch spans for the 1/8-inch material produced much lower modulus of rupture values for the 6-inch-per-minute head-speed than for the 4-inch-per-minute head-speed. The 1/4-inch material tested on a 4-inch span exhibited the same precipitous drop as illustrated in Figures 3 and 5 for head speeds over 4 inches per minute. A supplementary experiment was carried out using 1/8-inch untreated boards from company C tested on the 2- and 3-inch spans for head speeds of 2.00- and 4.00 inches per minute to determine if the same decrease in modulus of rupture occurred. The average values shown in Table 4 verify the fact that after a certain rate of fiber strain is reached a definite drop in modulus of rupture can be expected. This phenomenon calls for some explanation.

The ASTM tentative standard (D 1037-52T) "Evaluating the Prop-

Table 3. -AVERAGE MODULUS OF RUPTURE VALUES (PSI) FOR EIGHT HEAD SPEEDS IN SEVERAL COMMERCIAL HARDBOARDS TESTED OVER AN 8- AND 4-INCH SPAN

Board type				Head-speed (inches per minute)								
No.	Thickness (in.)	Class[a]	Company	0.05	0.15	0.25	0.50	0.75	1.00	2.00	4.00	L.S.D.[b] (psi)
				8-inch span								
1	1/8	UT	A	5630	5660	5900	5440	5870	5970	6090	6100	Insign.[c]
2	1/8	UT	B	5540	5680	5830	5880	5950	6030	5980	6100	250
3	1/8	T	C	8320	8620	8970	8770	9020	9400	9120	9720	660
4	1/4	UT	A	6060	6180	6220	6310	6550	6540	6440	6740	390
5	1/4	UT	C	4250	4420	4340	4480	4600	4550	4550	4540	Insign.[c]
				4-inch span								
6	1/8	UT	A	5810	5880	5520	5860	6080	6090	6040	6180	Insign.[c]
7	1/8	UT	B	4750	4900	4990	5020	5130	4990	5230	5360	340
8	1/8	UT	C	5130	5360	5270	5720	5590	5730	5750	5940	360
9	1/8	T	C	7330	7480	7560	8080	7990	8500	8120	8580	540
10	1/4	UT	A	5890	5620	5340	6080	5280	6040	6250	5520	Insign.
11	1/4	UT	B	5800	5760	5780	6090	6110	6310	6160	4640	390
12	1/4	UT	C	5000	5250	5170	5240	5330	5450	5500	3590	630
13	1/4	T	C	8120	8250	8130	8570	8630	8420	8310	5390	570

[a] UT = Untreated
T = Treated

[b] Least significant difference

[c] No significant difference among any of the head speeds

erties of Fiber Building Boards" has attempted to relate the variables of head speed, span, thickness, and rate of fiber strain in the following manner (1):

$$N = \frac{zL^2}{6d}$$

N = head speed in inches per minute
z = rate of fiber strain in inches per inch of outer fiber length per minute (0.005)
L = span in inches
d = thickness of specimen in inches

This relationship has been applied, without difficulty in the testing of wood members, although the rate of fiber strain (z) used for testing wood members is not the same as that used for fiberboards. The 0.005-inches-per-inch-per-minute rate of fiber strain recommended for the bending test of fiberboards does not permit a practical test procedure. For example: 1/8-inch material must be tested at 0.06-inches-per-minute head-speed using a 3-inch span. This very slow head speed certainly does not permit for efficient testing of large numbers of test specimens. If a faster head speed is used, for example 2.00 or 4.00 inches per minute and the rate of fiber strain kept constant, the span would have to be increased to approximately 17 and 24 inches, respectively, for the two spans. It is obvious that the 1/8-inch material could not be tested over such spans because of excessive deflections.

The application of the relationship in testing fiberboards necessitates making the assumption that this wood-base material will respond to the variables in a manner like that of wood in its natural state. An increase in rate of fiber strain in wood is accompanied by a gradual increase in modulus of rupture reaching the extreme where impact or shock-type loads have unit strength values approximately twice those of static-type loads. The phenomenon exhibited by the 1/4-inch material for the 4-inch span indicates that fiberboards do not react like wood as rate of fiber strain increases.

Close inspection of Table 4 and of Wilcox's curves (5) indicates that the critical rate of fiber strain may be different for each thickness of board, class (treated and untreated) and producer. Wilcox did not find a pronounced dropping off in modulus of rupture for the 1/4-inch material at the 4.00-inch-per-minute head-speed; whereas, all 1/4-inch boards tested at the same head speed in this later investigation showed definite decreases in both treated and untreated material from all producers.

There are several plausible explanations for these anamolous relationships. Wilcox (5) summarized the more tenable ones. The increasing shear stresses attended by short spans and high head speeds may be part of the answer. On the other hand, the temperatures which were used in manufacturing the commercial hardboards probably caused the boards to develop deformation and flow characteristics (rheological properties) such that the relationships of the rate of fiber strain were not the same as for wood. These same high temperatures and the incorporated resins also tended to make the wood fiber more brittle and thus less resistant to the higher rates of fiber strain.

The 1/8-inch material for Company A (Table 4) appeared to follow the rate-of-fiber-strain theory quite well. For example: a 4.00-inch-per-minute head-speed used over an 8-inch span and 1.00-inch-per-minute head-speed over a 4-inch span both had the same rates of fiber strain and the corresponding modulus of rupture values were the same. On the other hand, when the same comparison was made for the 1/4-inch material of Company C, two significantly different modulus

of rupture values were obtained even though the rates of fiber strain were the same.

Estimation of Critical Rate of Fiber Strain: The abrupt decrease in modulus of rupture for the ¼-inch material at the 4.00-inch-per-minute head-speed suggested the advisability of making a supplementary check on the same material by testing specimens over the 6-inch span to see if the curve for this span followed the 4- or 8-inch span trends at this head speed. The results of this experiment are given in Table 4 and indicate that the rate of fiber strain for the 6-inch span at the 2.00- and 4.00-inch-per-minute head-speeds did not exceed the critical point which would have caused a decrease in modulus of rupture.

In order to estimate better the critical value of rate of fiber strain, the ¼-inch material was tested over a 4-inch span using a 3.00-inch-per-minute head-speed. Table 4 indicates that these conditions definitely produced a rate of fiber strain that exceeded the critical point.

Careful study of the curves and values presented in Table 4 leads to an estimate of the critical rate of fiber strain as being between 0.33 and 0.50 inches per inch per minute, with the ⅛-inch material probably having a higher critical value than the ¼-inch material.

Different Approach to Recommended Head Speed and Span: The previous discussion should leave little doubt of the need for a different approach in the determination of a satisfactory head speed and span for evaluating the flexural properties of commercial hardboards. The statistical analysis of the test data for all types of boards investigated led to the conclusion that a range of head speeds might be recommended rather than a specific speed. The analysis showed that no differences in modulus of rupture values were obtained for a given type of board when head speeds from 0.50 to 2.00 inches per minute were used. This held for any span from 4 to 8 inches. A range of head speeds has certain definite advantages over a specific head speed. The 2.00-inch-per-minute head-speed is fast enough to provide for efficient use of testing time when only modulus of rupture is desired from the bending test. On the other hand, if modulus of elasticity and work values are desired, the 0.50-inch-per-minute head-speed can be used since this speed permits plotting a load-deflection curve. The modulus of rupture values from this type of test then can be compared with those

(Continued on page 90)

Table 4. RELATIONSHIP OF THICKNESS, SPAN, HEAD SPEED, RATE OF FIBER-STRAIN AND MODULUS OF RUPTURE

Thickness (d)	Span (L)	Head speed (N)	Rate of fiber-strain (z)	Company	Modulus of rupture [a]
inches	inches	in./min	in./in./min.		psi
1/8	8	0.05	0.000586	A	5650
"	"	0.50	0.00586	"	5850
"	"	1.00	0.01172	"	6000
"	"	2.00	0.02344	"	6100
"	"	4.00	0.04688	"	6100
1/8	4	0.05	0.00234	"	5750
"	"	0.50	0.0234	"	5900
"	"	1.00	0.0469	"	6100
"	"	2.00	0.0938	"	6150
"	"	4.00	0.1875	"	6200
1/8	3	2.00	0.1667	C[b]	5840
"	"	4.00	0.333	"	6310
"	2	4.00	0.6667	"	4410
1/4	8	0.05	0.00117	C	4300
"	"	0.50	0.0117	"	4500
"	"	1.00	0.0234	"	4550
"	"	2.00	0.0469	"	4575
"	"	4.00	0.0938	"	4600
1/4	4	0.05	0.00469	"	5150
"	"	0.50	0.0469	"	5300
"	"	1.00	0.0938	"	5450
"	"	2.00	0.1875	"	5475
"	"	4.00	0.3750	"	3600
1/4	6	2.00	0.0833	C[b]	5270
"	"	4.00	0.1667	"	5110
"	4	3.00	0.7500	"	4690

[a] Values read from curves
[b] Average of 10 test specimens

Table 5. -SUMMARY OF ANALYSIS OF VARIANCE FOR THE FIVE TYPES OF COMMERCIAL HARDBOARD TESTED ON AN 8-INCH SPAN

Variation due to:	Degrees of freedom	Significance by type (column 1, Table 3)[a]				
		1	2	3	4	5
Boards	1	NS	S	NS	S	S
Head speed	7	NS	S	S	S	NS
Boards x Head speed	7	NS	NS	NS	NS	NS

[a] S - Significant difference at 0.95 probability level
NS - No signficant difference

TABLE 6. SUMMARY OF ANALYSIS OF VARIANCE FOR THE EIGHT TYPES OF COMMERCIAL HARDBOARD TESTED ON A 4-INCH SPAN

Variation due to:	Degrees of freedom	Significance by type (column 1, Table 3)[a]							
		6	7	8	9	10	11	12	13
Boards	4	S	S	S	S	NS	S	S	S
Head speed	7	NS	S	S	S	NS	S	S	S
Boards x Head speed	28	NS	NS	NS	NS	S	S	S	NS

[a] S - Significant difference at 0.95 probability level
NS - No significant difference

Plaswood, New High-Density-Chipboard[1]

GEORGE D. GOODFELLOW

President and General Manager, Canadian Plywoods Limited, Montreal, Quebec

Development, manufacture, uses and limitations of new high density chipboard is described, as well as potential improvements. Besides making possible a new product of many uses, process greatly broadens utilization of total content of tree.

THE FOREST PRODUCTS Research Society was formed primarily to do two things: first, to bring about a closer relationship between our wood-using industries and those engaged in forest products research; and, second, to encourage and promote efficient utilization of wood and other forest products. Trafalgar Mills, the manufacturers of Plaswood, are particularly interested in the latter phase of the Society's activities.

The company operates a mill at South Nelson, N. B., that does nothing else but convert what was formerly wasted wood into hard, high-density general utility panels which are being widely used throughout Eastern Canada in the construction industry and, to a lesser extent, in the furniture trade.

Trafalgar Mills are constantly striving to increase utilization of the sawlog. About 50 percent of the round log is normally lost when it is converted into flat lumber. At Trafalgar Mills a Swedish frame saw is used which increases the percentage saved to 60. The remaining 40 percent goes into narrow lumber strips, lath, the Plaswood mill, or firewood. The sawdust is used as fuel to heat the plant. The refuse burner no longer used stands as a monument to a more wasteful era.

[1] Presented at meeting of the Forest Products Research Society, Eastern Canadian Section, March 5–6, 1953, at Toronto, Ont.

In 1949, the company contacted a group of Americans who were experimenting with a chipboard called Plaswood. The pilot plant at Wilton consisted of a single flat-bed press which turned out a low-density board measuring 2′ x 8′, under a long slow cycle. Many experiments had to be carried out to produce the boards quickly in the hot press in multiples of ten. On more than one occasion the steam generated from the excessive moisture in the mixture in the press caused the boards to burst into fragments.

By early in 1950 the mill was turning out a 4′ x 8′ sheathing board with a density of only 28 pounds per cubic foot. Tests carried out by the Forest Products Laboratory proved satisfactory. This first board wasn't a success, mainly because many applicators failed to observe the proper application techniques. Instances of buckling were reported and, upon inspection, it was almost invariably found that the applicator had failed to leave an 1/8″ expansion joint between sheets, or had left them carelessly stacked out in the rain, uncovered, or both. The 1/8″ expansion joint is extremely important in Plaswood applications, for the board is exceptionally rigid. Plywood panels if placed too closely together tend to compress or press into each other, when they absorb moisture. In fact, they crush together slightly at the joints before showing any tendency to buckle. But Plaswood is different. The boards are too rigid to crush together; instead, they buckle.

Improvements

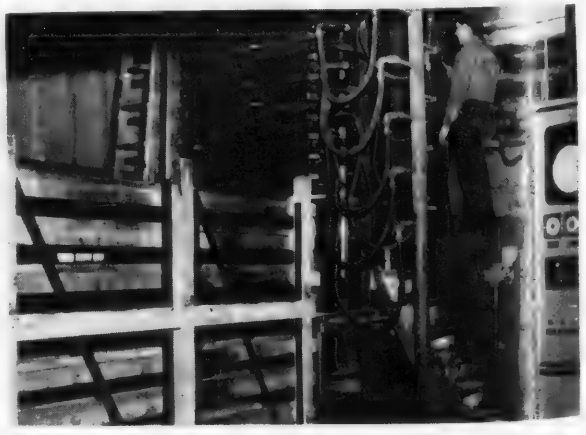
It was also felt that the board because of its low density lacked sufficient strength. Therefore, its manufacture was discontinued, and the mill concentrated on producing a board with a density of 42 pounds per square foot. Meanwhile, the air drier was replaced by a rotary-type drier that proved more efficient and had no tendency to damage the wood fibres of chips fed into its cylindrical drum. An additive was applied to the chips to increase their resistance to moisture absorption. During this period, experiments revealed that spraying urea-formaldehyde resin gave the best bonding results.

The manufacture of Plaswood seems deceptively simple. First, the wood left over from the operations of the nearby Nelson sawmill is brought to the Plaswood mill by conveyor belt. Last year's consumption reached 12,000 tons.

The second step consists of mechanically processing, classifying and reducing the slabs, edgings and end trim to the required size. The chipped wood is then blown through a pipeline into a 60-foot long cylindrical drier 6 feet in diameter which rotates slowly while hot-air, fanned in from an oil burner, reduces moisture content to approximately 2 percent.

(Continued on page 90)

Typical use of new board.



Hot press used in panel production.

The Preparation, Handling, and Transportation of Pulpwood East of the Rockies[1]

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The Pulpwood Industry has sometimes been slow in adopting efficient material handling methods—partly because economic need for labor saving devices has arisen rather lately. Practical machines and methods now in use east of the Rockies are influenced by regional conditions. In the face of increasing labor shortages, machine handling of pulp wood in key operations is certain to be stepped up.

OVER-ALL SCOPE and size of the many material handling endeavors carried on by the Pulpwood industry can be judged by the fact it consumed over 24 million cords, or 50 million tons, of pulpwood in the year 1951—and handled each cord of wood from two to twelve times. This means 50 million tons of pulpwood were cut, skidded, hauled, loaded onto railroad cars, barges, or trucks, driven down streams, rehandled two or three times at the mill—all before being placed on the woodyard conveyor to the woodroom for further processing into a raw material substance which could be utilized by the Pulp and Paper Industry.

In spite of the tremendous tonnage of raw material which must be handled every year, material handling methods requiring manual labor are still predominantly used by the Pulpwood Industry today. In touching on a partial explanation for those handling methods adopted by this industry, and to further qualify the still present practice of handling great quantities of this product by hand labor, four of the more important factors affecting the production of pulpwood should be understood.

(1) Pulpwood is heavy and must be handled on a stick by stick basis by hand or in economical sized units by relatively large and expensive pieces of equipment. Green Southern Pine, for example, weighs over 5000 lbs. per 128 cubic foot rough cord and can range from 40 lbs. to 100 lbs. per average sized stick. Thus pulpwood is a raw material which is often too heavy to handle, on a stick by stick basis, by hand and too light to justify use of mechanical equipment.

(2) Pulpwood is an awkward material to handle: By its very nature pulpwood usually requires at least one manual handling before grouping into payload bundles by mechanical equipment is possible. Pulpwood bolts must be placed in a pile, either by the cutter or some other designated individual, before any effective material handling method requiring economical payload units can be employed.

(3) The supply of pulpwood is furnished by multitudes of small independent producers: The idea that mechanical handling equipment is often expensive arises from the fact that low profit, risk, and interest return margin per cord of wood will seldom permit use of mechanical equipment unless large volumes of pulpwood are to be handled. Keep in mind that 84% of all the pulpwood produced in this country during the year 1950 was by small independent pulpwood producers, many not producing more than 800–1000 cords per year.

(4) The adoption of new material handling ideas and methods are often retarded by a conservative attitude toward a changing situation: By a changing situation is meant the shortage and high cost of labor, a reduced productive capacity per individual woodsmen when using non-mechanized equipment, the necessary logging of terrain previously considered a submarginal chance, and the demand for pulpwood in quantities exceeding all previous records.

Recognizing that certain phases in the production of pulpwood will usually require some man-handling, the industry at the present is concentrating mechanization efforts upon those phases in the cycle of pulpwood production which promise the greatest financial savings and increase in production. Providing certain conditions exist, members of the Pulpwood Industry are quite conscious of the fact that animal and man handling can produce cheap and large quantities of pulpwood. However, with the passing of every year—every month—there are pulpwood producing regions that are rapidly approaching or have approached a situation such as this: We have the horse but not the man. We have the man, but not the horse. Or, we have both, but no large tracts of timber.

The "Good Old Days"—to which many oldtimers proudly refer when speaking of costs and production—will never return. For, within a few years, the Pulpwood Industry will have experienced such a taste of mechanization that many of those very efficient methods employed when animal and manual handling was at its peak will either be forgotten or the complete combination of men, animals, equipment, and timber will be non-existent.

Generalized Picture of Pulpwood Production

The five pulpwood producing regions, with which I am concerned, all have conditions and specific characteristics differing from each other.

(1) The Lakes States Region is characterized by a shortage of labor, is highly mechanized, and the eight foot pulpwood cut in this region is handled very well by mechanical equipment.

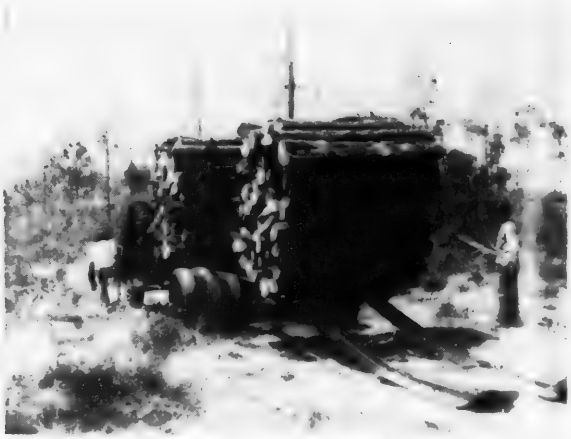
(2) The Northeast Region. Imported Canadian woodsmen have assured an ample labor supply in the past, material handling methods are not highly mechanized, and wood is cut in four foot lengths—resulting in pulpwood difficult to handle mechanically, unless slings are used.

(3) The Appalachian Region. Making use of handlabor, material handling methods are not mechanized. Wood is cut in lengths of five feet, proving difficult to handle mechanically. (No further reference will be made to this region in this paper for methods seem to be a combination of those employed in the South, Northeast, and the Lake States).

(4) and (5) The Southeast and Southwest Regions. Although labor is often in good supply, signs of shortage are appearing in some areas. Industry members are very progressive in the development of mechanical

[1] Presented at meeting of the Forest Products Research Society, Upper Mississippi Valley Section, December 9, 1952, at Wausau, Wis.

Loading drays with a hydraulic loading attachment mounted on the skidding tractor.



Dixie pallet system—bobtail truck.

Lift truck equipment with fork and arm clamp.

Lift truck equipped with a clamshell grapple which can be revolved 360 degrees.

equipment. Wood is cut in five foot lengths, permitting effective handling, if slings are used.

Cutting Operation

The felling, bucking, and limbing of pulpwood is usually performed by a single woodworker using an axe and some type of power or hand saw. In the Lake States and the Northeast a one man chain saw has become quite popular while the wheel mounted circular saw and the two man chain saw are favored in the South.

Wood is either cut "tree length" or bucked into short bolts at the stump—"stump-cut wood". In the South, most "stump cut" wood is loaded directly onto trucks without prior piling, while operators in the Lake States and Northeast regions require the cutters to pile this wood next to a skid trail for piecework payment and transport at a future date. "Tree length" wood is neither bucked or piled at the stump.

Skidding Operation

On operations where wood is cut and piled, mechanical material handling methods become practical. A large percentage of the piled wood in the Lake States and Northeast Regions is loaded in the winter by hand onto drays or sleighs. Horses or tractors are used to transport this wood either to a river dump or to a road for loading onto trucks or larger sleighs. Michigan operators, employing a small crawler tractor-loader equipped with a hydraulically operated set of jaws, can mechanically load wood from pile to dray, furnish the motive power to bring wood to a road, and transfer the load onto some types of trucks. (Figure No. 1). In the more mountainous areas of this Lake States region, tractors with sulkies successfully skid piles of 8-foot pulpwood, contained by lock-type chokers. This permits the mechanical transfer of economical sized bundles onto trucks with a simple jammer.

Known as "yarded" wood in the Northeast, "tree length" wood is skidded by single horses or small tractors to a truck road or to high ground before being bucked into short lengths and piled for future forwarding or transport. "Tree length" wood in the South is bucked and loaded into iron pipe ballets at some point adjacent to a truck road or is loaded directly onto trucks by hand. Long lengths of pulpwood are often skidded in all regions with tractors and sulkies to a portable slasher saw where reduction into short lengths is accomplished. Several large operators truck these long lengths to the mill where multiple slashers perform the job of bucking.

Loading Trucks

In regions where the supply of labor is good and pulpwood size does not require mechanical handling equipment, man handling is the principle method employed to load trucks or sleighs.

In mechanizing, the South favors the winching of loaded steel pallets onto a truck frame assembly with power supplied by a small winch mounted behind the truck cab. With pallets preloaded, five men (equipped with a D-2 tractor, four pallets, a pair of iron detachable slides so pallets may be drawn about the woods, one circular wheel mounted saw, and a three cord capacity truck equipped to handle these pallets) can deliver 3 cords per man day from stump to the mill when working a 10 hour day and hauling 30 miles one way. (Figure No. 2).

Crane loading 4-foot hardwood in Maine.

A simple overhead jammer for unloading trucks in Michigan.

Crane unloading a truck in Michigan.

Loading rack cars in South Carolina with crawler crane and slings.

This figure is to be compared with a recent survey in the South which indicated a production average of one cord per man day. In Louisiana one operator procures farmer cut wood by dispatching 34 detachable truck frames or pallets of 4½ cord capacity. These frames are easily winched preloaded onto a truck for delivery to the mill. With mechanical means of unloading at the mill, a pallet system permits a small operator to produce efficiently by keeping his hauling unit on the road with loading and unloading time reduced to a minimum.

Small producers in the Lake States make use of a boom and hoist loader mounted on the truck which enables the handling of wood singly or in small bunches. Larger operations employ semi-mobile gravity swing-boom jammers which can transfer 1¼ cord loads from drays to trucks.

Wood piled adjacent to truck roads is loaded onto trucks with a skid-loader or a ½ yard crawler crane equipped with a ½ cord capacity clam-shell grapple—a tractor mounted loader equipped with jaws so a ¾ cord load of 8 foot pulpwood may be picked up, transported, and deposited on a truck. Production may average 115 cords per 9 hour day on a 30 mile round trip haul with either crane or skid-loader.

Gaining popularity throughout the country, especially in the Lake States, the carry-lift type machine (Figure No. 3) can perform most of the material handling endeavors claimed by the tractor mounted loaders of the same type. With the advantage of mobility, reduced maintenance costs as compared with crawler units, and a special attachment by which trucks and R. R. cars can be loaded and unloaded from the side (Figure No. 4) many operators express favor toward the use of this wheel mounted loader.

The last three machines mentioned can eliminate the cost of snow removal from piles and experience little difficulty when loading frozen piles of pulpwood.

In the Northeast portable conveyor loaders permitting the stick by stick loading of trucks have been in use for many years. Recently, a ⅜ yard capacity truck mounted crane, equipped with a 1200 lbs. clam-shell grapple has been put to work—especially when handling heavy hardwood. (Figure No. 5). This machine can load coniferous pulpwood at a rate of 80–90 cords per 10 hour day. One company is loading tree length hardwood pulpwood onto large diesel truck trailer units with ¾ yard crawler cranes equipped with a 40 foot boom and a set of heavy log tongs.

Unloading Trucks and Transferring Wood to Railway Cars

Here again man-handling accounts for most of the wood handled at this phase of the production of pulpwood—especially in the South and the Northeast. This fact is often difficult to comprehend for pulpwood on the truck is available in units of volume which facilitate effective transferring and unloading by mechanical means. Simple divider stakes on the truck rack will permit a selection of any size bundle to assure that the capacity of a mechanical loader is not exceeded. In some regions the necessity of using large numbers of box cars in lieu of specially designed pulpwood rack cars account for a great deal of this manual transfer of wood from trucks to rail cars.

For a number of years operators in the Lake States region have been conscious of the savings to be realized by handling pulpwood in bulk at this

Transferring wood from storage to rack car at rail concentration yard in Alabama. Note special goose-neck boom.

Tournacrane handling pulpwood in South Carolina.

Fork lift truck handling pulpwood at rail concentration yard in Alabama.

Dumping truckloads of wood into water storage in Maine.

point. This is shown by use of inexpensive jammers to transfer 2½ cord loads of 8 foot wood from trucks to R. R. Cars at a rate of 120 cords per 9 hour day. Hoisting with one drum of the double drum winch, the second drum is used to locate the open sided cars as loading progresses. Figure No. 6). Many companies make use of cranes equipped with clam-shell grapples to perform this task—especially if wood must be piled beside the spur track and loaded into cars at a future date. (Figure No. 7).

Within the last ten months, companies in the South have constructed pulpwood concentration yards equipped with spur tracks and sufficient area to store large volumes of wood. Using a split sling with a toggle pin trip, 1½ to 1¾ cord bundles are transferred from trucks to rack cars or to storage. Bundles placed in storage are contained with size ¾″ x .035″ steel strapping. The ¾ yard crawler cranes (Figure No. 8) operating at a number of these yards are unable to store wood outside of its 15′ operating radius from the car. Wheel mounted cranes, however, can transport wood any reasonable distance from storage to rack car. (Figure No. 9). Tractor-mounted loaders are competing with cranes to do a more effective job at a lower cost per cord. (Figure No. 10) From all indications fork lift trucks, which have proved very successful in other lines of endeavor, will, with necessary minor modification, prove a good, inexpensive loader. (Figure No. 11). These cranes and loaders, provided scheduling of trucks is ideal, can load 220 cords per 9 hour day.

Removing wood from water storage with a jackladder conveyor system, one big company in the Northeast dumps wood into special open top pulpwood cars at a rate of 72 cords per hour. These cars, of 16 cord capacity, are unloaded at the mill by securing each car to a hydraulic side dumping platform, tripping the door-like sides, and tilting the car so wood is spilled into a storage pond. Trucks are unloaded in like fashion, except wood is dumped off the back. (Figure No. 12). Other companies in this same region are using ⅜ yard truck mounted cranes equipped with ⅛ cord capacity clamshell grapple to effect this transfer from truck to open top pulpwood cars. Thought has been given to the use of a single sling and a ¾ yard crane to unload one tier at a time from trucks into a frozen river dump where the conserving of space is an important factor.

A great quantity of pulpwood today is still shipped by rail in box cars. Confronted with an expensive manual loading charge, the industry is forced to use this type car until replacements by pulpwood cars is completed. In realization that this might be a long time into the future, and with many attempts to reduce loading and unloading charges by use of mechanical equipment, studies have been conducted to determine the relative merits of shipping pulpwood by box car in the form of chips.

Long Distance Transportation

Testing in the Northeast indicated that a 40 ft. box car with a 2960 cubic ft. capacity scaled 13.45 cords when a conversion factor of 2 0 ft. per 128 cubic ft. peeled cord was used. This car could normally carry 19 cords of 4′ rough pulpwood. When blown into a box car, chips pack more tightly and a factor less than 2 0 cu.

(Continued on page 91)

Weed Control[1]

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The use of chemicals for weed control has increased greatly during the past years until it has become an important and integral part of American agriculture. With the development of new and more effective chemicals for weed control, and with the general trend of lower prices for these chemicals, we can look forward to their wider use. In forestry chemicals are of specific value for control of brush, sterilization of plant growth in storage yards, and selective weed control as needed.

Classification of Herbicides

CHEMICALS MAY BE classified according to their use or according to their action on plants. There is no hard and fast category into which a given chemical may fall because timing of application, rate of application, and the type of plant involved may modify the use of the chemical. For example, sodium chlorate is customarily considered as a soil sterilant. However, if used at sufficiently light rates it may act as a selective weed killer for broadleaf plants. Keeping this thought in mind, then it is possible to make the following classifications of the herbicides now in use:

Soil Sterilants

Soil sterilants are chemicals that when applied to the soil in sufficiently high rates will prevent the growth of most species of plants from one to several years depending upon the conditions. These substances usually are not subject to rapid breakdown in the soil as is the case with other chemicals, and moreover they usually possess considerable toxicity to a wide array of plants. The principle use of soil sterilants is for small patches of perennial weeds or for weed control on rights-of-ways. Such substances as sodium chlorate and arsenic are widely employed as permanent soil sterilants.

Sodium Chlorate. Sodium chlorate is one of the old, well known herbicides and soil sterilants. The herbicidal properties of this compound were discovered around 1917 and it has enjoyed wide usage for control of perennial weeds since that time. It is especially effective on Canada thistle and many grasses although it is toxic to practically all types of plants. This substance should be handled carefully to avoid possible fire hazard.

Sodium chlorate is used as a soil sterilant at dosages ranging from 3 to as high as 8 pounds per square rod. It controls most types of vegetation and frequently is employed as a spray solution containing one pound per gallon of water.

Arsenicals. Arsenic in various forms has been used for a number of years as a soil sterilant. The active ingredients of all arsenical compounds is arsenic trioxide (As_2O_3). Arsenic is usually highly effective on plants high in sulphur such as legumes, Canada thistle, and white top, but may be considerably less effective on the grasses than other chemicals.

Arsenic is available as a herbicide in several forms: arsenic trioxide, As_2O_3, which is commonly called dry white arsenic and is the least soluble of the forms of arsenic available and usually is applied dry. It is also one of the safest forms of arsenic to use. Several soluble forms of arsenic are available; those used most frequently are sodium arsenite or sodium acid arsenite.

Arsenic is a highly toxic compound to all classes of animals. It should be handled very, very carefully to avoid possibility of poisoning.

Boron Compounds. Like arsenic there are many compounds of boron available but the active ingredient of the borate compounds is boric oxide, B_2O_3. Most of the borate weed killers are mixtures of the sodium salts of the various boric acids. The two important compounds of boron that are used as weed killers, however, are sodium tetraborate or borax and sodium pentaborate.

There is a great species difference in plant tolerance to boron compounds. However, the general range of boron compounds is equivalent to 500 to 1,000 pounds of boric oxide per acre.

Borates have a distinct advantage over the two previously mentioned soil sterilants in that they are neither toxic as they are normally used nor do they present a fire hazard. Borates also are less soluble in water so that they tend to have a longer residual action in the soil although their initial toxicity may be lower than either chlorate or arsenic.

Chlorate Borate Mixtures. In an attempt to reduce the toxicity and fire hazard of chlorate and also to take advantage of the somewhat longer sterilizing action of the insoluble borate, mixtures of these two chemicals are available for soil sterilization. The rate of application of this mixture varies with the percentage composition of the preparation.

Chlorphenyldimethylurea. CMU is the first true organic sterilant. Other organic chemicals such as 2,4–D if applied at a sufficiently high rate frequently give soil sterilization for varying lengths of time. However, in the case of CMU, the substance is highly and generally phytotoxic and has a long residual effect in the soil. CMU appears to be quite resistant to attack by microorganisms and although it is soluble in water, it is so strongly adsorbed by the soil that it remains at toxic concentrations for a long period of time even under heavy rainfall. However, because it is strongly adsorbed by colloidal substances and also probably by organic matter, one can expect considerable variation in results with this material from one soil condition to another.

CMU appears to possess greatest toxicity toward grasses, although it is toxic to most species of herbaceous plants against which it has been tested thus far. Some of the brushy plants may have considerable tolerance for the material. As a soil sterilant CMU is used at dosages ranging from 10 to as high as 60 pounds per acre. Under particularly humid and adverse conditions it might be more economic to use this material at a lighter rate of application, let us say 15 to 20 pounds per acre and repeat the application yearly, than to attempt to use a single heavy dosage and expect a two or three year soil sterilization.

CMU is a grayish-white crystalline product having a very low solubility

[1] Presented at meeting of the Forest Products Research Society, Pacific Northwest Section, February 6, 1953, at Tacoma, Wash.

[2] Presented at meeting by Dr. A. W. Stout, Western Pine Association, under title "Herbicides."

in water and a comparatively low solubility in most organic substances. For this reason it is not possible to formulate CMU as a liquid concentrate; rather it is formulated either as pelleted, granular, or as wettable powder.

Temporary Soil Sterilants

The temporary soil sterilants are substances which give a very short period of soil sterilization for from one month up to as much as a year depending upon the condition and the rate of application. It should be noted that many herbicides if applied at sufficiently high rates will give a temporary soil sterilization. However, there are comparatively few used for this purpose.

Ammonium sulfamate. Ammonium sulfamate, or amate, is one of the more popular and well known temporary soil sterilants. It is used primarily for control of brushy plants for which it appears to be best suited. It should be noted that as a foliage application amate is more generally toxic to brushy plants than almost any other substance known. It is also highly effective on many other plants when used at concentrations high enough to give a temporary soil sterilization. This substance breaks down rapidly in the soil under the influence of moisture to form the common fertilizer ammonium sulfate, and as such effects the successful reversal of herbicidal action.

As a temporary soil sterilant ammonium sulfate is used at rates of 100 to 800 pounds per acre during the dryer months of the year. If conditions are not proper, however, and there is a ready availability of moisture, the material will break down and defeat the purpose of the application.

Ammonium sulfate is a grayish-white crystalline product that is highly soluble in water. As a spray it is normally used at a concentration of ½ to one pound per acre.

Salts of Trichloro Acetic Acid. Salts of trichloro acetic acid, or TCA, have been introduced within the past few years as a temporary soil sterilant, particularly for the control of grassy plants. At lighter rates of application, this substance exerts a somewhat selective residual action in that a number of broadleaf crops such as some legumes will tolerate dosages of this material as high as 12 to 15 pounds per acre while many of the annual grasses such as cheatgrass and water grass are successfully controlled by this treatment. For control of perennial grasses dosages of as high as 120 to 160 pounds per acre may be required although in some instances successful control has been achieved with as little as 40 to 60 pounds per acre. TCA acts primarily through the soil in that it seems to be more readily adsorbed by a plant's roots than by the tops. This means that TCA should be applied when there is adequate soil moisture or should be worked into the soil by some tillage operation.

Contact Herbicides

Contact herbicides are substances which kill only the portion of the plant or vegetation with which they come into contact. These materials are usually non-specific in their action being injurious to all types of vegetation. Some materials do exhibit a certain degree of specificity in the fact that they are more effective against certain plants than others but even in these cases they show some degree of injury to other plants.

Phenols. Substituted phenols exhibit a high degree of toxicity to many plants. It will be recalled that one of the first organic compounds introduced for weed control was a dinitro phenol. These substances are generally quite effective on broadleaf plants but are not so specifically effective on grasses. Consequently, since oils are quite effective on grasses, phenols are frequently used to fortify oils making a highly effective contact weed killer.

Two principle phenols are now used as a herbicide. They are dinitro-orthosecondarybutyl phenol and pentachlorophenol. Pentachlorophenol is about ⅓ to ¼ as toxi pound for pound as dinitrophenol but it is much cheaper of the two. Dinitrophenol is generally more effective on broadleaf plants where pentachlorophenol is more effective than the dinitrophenol on grasses.

Aromatic oils. Petroleum and coal tar are complex substances composed largely of hydrocarbon materials and oxygenated derivatives of hydrocarbons. Many groups of compounds may be separated in the refining process from these complex mixtures and depending upon the chemical nature of the group of compounds refined will have special uses. In the process of refining there will remain a residue of a complex mixture of aromatic and unsaturated hydrocarbons that have been found to be highly phytotoxic. These so-called aromatic oils will contain such substances as xylene, biphenyl, phenanthrene, straight chain and branch chained unsaturated substances, cyclic unsaturated olefins; perhaps in the case of coal tar products creosols and cresylic acids.

The aromatic oils are highly phytotoxic to all types of vegetation but are not translocated in the sense that 2,4–D and other growth regulating chemicals are translocated. These materials are effective contact sprays and are frequently used on rights-of-ways as herbicides.

Selective Herbicides

Selective herbicides are materials that when applied to a mixed stand of plants will successfully destroy certain selected species in that mixed stand of plants. In some instances the herbicide is highly effective for the control of broadleaf plants and leaves grass plants relatively unharmed. In other instances the material may be effective for the control of weedy grasses and leave broadleaf plants relatively unharmed.

Carbamates. Derivatives of N-phenyl carbamate acid and substituted N-phenyl carbamate acid have recently come into prominence as selective residual herbicides for the control of weedy annual grasses and a limited number of broadleaf plants that are susceptible to them. They are used at rates ranging from 2 to as high as 8 or 10 pounds of technical grade per acre for selective grass control and higher for control of perennial grasses.

Synthetic Growth Regulating Chemicals 2,4–D

As a result of early tests demonstrating the effectiveness of this compound 2,4–D has developed into one of the major herbicides of today.

The volume of carrier with which 2,4–D is applied will influence net results. Applications with water at gallonages of 20 to 100 gallons per acre appear to be optimum for most plants. Lesser volumes of application usually are not so effective, and similarly, high volumes may not be so effective. It has been shown that there is a possibility of an interrelationship between the volume of application and the rate or amount of chemical applied per acre. Thus each dosage level may also have its optimum level of volume application.

The parent 2,4-dichlorophenoxyacetic acid is a white crystalline organic acid, too insoluble in water to be used directly for field application. The chemical is, therefore, processed to form sodium, ammonium, and amine salts and esters, in order to get the parent substance in a form where it can be used. Each of these different formulations have their own peculiarities, even to the extent of having slightly different effects on the plant.

On the whole, reasonable precautions in the handling of this chemical should present no undue health hazard to the operator or to livestock. It does seem to increase the palatability

of sprayed plants which otherwise would not be eaten.

The greatest danger from the use of 2,4 D is damage to susceptible crops by the drifting of the chemical, whether as a vapor or as spray particles. The careless and improper use of 2,4–D has caused widespread damage to crops in certain areas of the United States. Most of the damage caused by 2,4–D results from improper or careless use of the material therefore, all safety recommendations should be followed carefully.

Precautions:

1. 2,4–D is difficult to remove from spray equipment. It must be removed before spraying with other materials or injury to other crops may result. To clean a sprayer thoroughly, (a) rinse with fresh water several times, flushing it through the pump and hoses, (b) fill the tank with water and add one pound of lye, soda, or sal soda for each 100 to 150 gallons of water and let it stand overnight, (c) start the pump and circulate the solution for a few minutes and then pump out, (d) rinse with two or three washes of clean water.
2. Avoid small droplets or fogging of the spray by using the largest volume of water practical along with the use of a pressure low enough to give large droplet size in conjunction with a nozzle having suitable orifice size. Remember, atomization or fogging can be caused by either high pressure or small nozzle openings.
3. Make sure all equipment is in good working order without leaks and having a positive shut-off valve.

Mixing Hormone Type Sprays with Other Type Herbicides

Mixtures of 2,4–D and the other hormone type herbicides with such chemicals as ammate and TCA for the control of brushy plants have been used. Some of these mixtures are used for the control of certain perennial weeds. These combinations as foliage sprays during the summer months have proven far more effective than the hormone type herbicides alone. A great deal of investigation on these combinations would be justified, particularly where we encounter hard to control perennial weeds.

It would appear that there are three situations where one interested in forest products would be concerned with chemical weed control. These are: Control of brush, sterilization of plant growth in storage yards and around mills, and selective weed control. In this latter case, such problems as the control of alder in coniferous plantings, destruction of certain perennial weeds along rights-of-ways might be the major problems.

Brush Control

The control of brushy species of plant may be achieved with one or two types of application of chemical weed control, either foliage application where the chemical is applied in considerable volume of carrier to the plant after it has leafed out or secondly basal application where a concentrated oil solution of chemical is applied to the lower 18 inches of the stem or trunk.

Foliage application for the control of brushy species is always carried out during the spring and summer months and is largely limited to this time. There are many instances where this type of application is the one most readily used. This would hold true particularly in the case of very rank and dense brush of limited size that makes penetrability of equipment and the operator somewhat difficult. Again this type of application is the only kind available for use with any type of air craft.

In foliage application for brush control, several types of materials may be used. The soil sterilant ammate and sodium chlorate can be used effectively for the control of many species of brush in a foliage application. In this instance the materials are mixed in water employing one pound of ammate or sodium chlorate per gallon of water. It should be noted that these two chemicals must be used separately and a mixture of them should never be employed because of the attending danger from the formation of ammonium chlorate. Such a mixture as previously described will be applied at the rate of 200 to 300 gallons per acre on a solid stand of brush 6 feet high. At this rate the sodium chlorate would cost in the neighborhood of $12.00 per hundred gallons of spray and the ammate or ammonium sulfamate would cost in the neighborhood of about $17.00 per 100 gallons of spray.

The brush killer mixture of the esters of 2,4–D and 2,4,5–T are also frequently used in foliage application for brush control. Here three pounds of the mixed chemical, that is, the parent acid of the mixture is used in 100 gallons of spray solution. The cost involved in this case is approximately $8.00 per 100 gallons of solution but the species effectively controlled by this mixture will be somewhat less than either the ammate or the chlorate. The effectiveness of this combination can be increased materially by the addition of ten pounds of the sodium TCA, this combination is most effective for control of alder, willow, scotchbroom, blackberry, ash, elderberry and poison oak.

Recent Development

A recent development in chemical brush control that is proving to be of immense value for this purpose is the so called basal application of the growth regulator mixtures. This treatment consists of making application of a concentrated oil solution of the ester form of the growth regulators to a portion of the lower stem of the plant. Water has been found ineffective as a carrier for this purpose so that full reliance must be placed on one type of oil or another as the primary carrier.

The mixture used is made up by dissolving 5 gallons of four pound per gallon 2,4–D, 2,4,5–T ester formulation in 100 gallons of oil. More correctly stated 5 gallons of this mixture is used to make up 100 gallons of final spray. This gives a concentration of approximately two and one-half per cent or 25,000 parts per million. For a wide range of species it has been found that the optimum range of concentration is between 20 and 30,000 parts per million or two to three per cent.

The principal oil used for this work has been of the diesel oil or stove oil class, but our investigation shows that the more highly aromatic weed oils such as Standard general and Avon weed killer or Shell 20 weed killer are more effective as carriers for this type of work than the diesel oil type. Table two shows a comparison of these different materials.

Almost any type of equipment may be used for this application, ranging from a three gallon knapsack sprayer to a more elaborate power equipment. The nozzles used to apply this material are the standard weed control nozzles mounted in a U shape piece of pipe. The diameter of the U shaped pipe should be large enough to leave a very ample margin between the nozzle and the trunk of the tree when the open end of the U is passed around the tree. The nozzles should be of the low volume category as there is no need to drench the plant.

Effectiveness

The effectiveness of this treatment is dependent upon bark absorption of the chemical so that bark rapidly becomes a limiting factor of effectiveness. On thick bark species such as oak, a trunk diameter of 4 to 6 inches may indicate sufficiently thick bark as to make the treatment impractical where as on alder or willow even

TABLE I

EFFECTIVENESS AS A FUNCTION OF CONCENTRATION

MATERIAL	CONCENTRATION	PER CENT CONTROL
2,4-D - 2,4,5-T	1.2%	31.0%
2,4-D - 2,4,5-T	2.4%	72.0%
2,4-D - 2,4,5-T	3.6%	65.0%

TABLE II

TREATMENT	CARRIER	CONCENTRATION	PER CENT CONTROL 10 MONTHS AFTER TREATMENT
2,4,D	Diesel	3.6%	40
2,4-D	Diesel	2.4%	62
2,4-D	Shell 20	2.4%	89
2,4-D	Light oil	2.4%	42
2,4-D	Standard general	2.4%	82

TABLE III

MATERIAL CHEMICALS FOR WEED CONTROL

MATERIAL	COST PER LB.	USES	RATES
Ammate (Ammonium sulfamate)	15-20¢	Brush	0.5 - 1 lb/gal spray to wet
		Summer sterilant & Contact spray	1 -3# /sq rod
		Control of herbaceous perennial weeds	2 - 6# /sq rod (apply during dry period)
		Pre-emergence	20 - 40# /acre
Borax	2-3¢	Soil sterilization	15 - 30# / sq rod
Arsenicals	6-10¢	Soil sterilization	8 - 16# / sq rod
CMU	$3.50-4.00	Soil sterilization (very effective on grasses)	20 - 40# / acre
2,4-D	1.00-1.50	Selective in grain and grass	1/2 - 1#/acre
		Non selective for perennial weeds & brush (use ester form.)	1 - 3# / acre
2,4,5-T	2.00-3.00	Brush, particularly blackberry	3 - 8# / acre
MCPA (similar to 2,4-D)	Non-Commercially available in U.S.	Selective in grain and grass	1/2 - 1# / acre
		Perennials	1- 3# / acre (Canada thistle whitetop)

larger trunk diameters can be treated effectively. The basal treatment may be applied at any time of the year and is not limited merely to winter or early spring. Summer applications appear to be equally effective as later.

On thick bark species where absorption of our basal treatment becomes a limiting factor incisions in the bark made by chopping may be used to circumvent the problem. In this case the concentrate used in basal application is sprayed or injected directly into the incision. These incisions should be made no further apart than 4 inches around the circumference of the plant to be treated.

The control of certain herbaceous plants in drying yards and along rights-of-ways often is a serious problem. In this instance it is desired to remove all vegetation and to prevent its regrowth for as long as possible. Reliance must be placed on the soil sterilants for this type of weed control program. There are several chemicals that may be used for soil sterilization—arsenic, sodium chlorate, sodium chlorate borate mixture and the new organic chemical CMU. Arsenic is one of the older soil sterilants but has taken something of a back seat to some of the other soil sterilants because of its toxicity to warm blooded animals and its lack of effectiveness against grassy plants. This material does provide about as long sterilization as any chemical known if used at sufficiently high rates.

Sodium chlorate is an effective soil sterilant and under most conditions gives excellent control of all types of plants. This material has certain weaknesses however, in that it is readily leached from the soil by heavy rainfall and because of the danger attendant with its use, because it is a strong oxidizing agent. This material when mixed with organic matter forms a very combustible mixture. The danger from this source with sodium chlorate has been minimized by mixing it with certain other salts but the chlorate borate mixture is the safest of any of the mixtures. For soil sterilization sodium chlorate is applied at the rate of four to six pounds per square rod or between 640 and 960 pounds per acre at the tail end of the rainy season. However, this substance is used usually only against small patches of perennial weeds and where major sterilization of the area is desired, chlorate borate mixtures are used.

The chlorate borate mixtures may be obtained containing from about 30 per cent sodium chlorate to approximately 45 per cent chlorate. The chlorate is the principal active ingredient with the borate present to reduce fire hazard and provide a longer sterilizing effect in that the borate is effective for the control of certain seedling weeds. The chlorate borate mixtures are applied at the rate of three to five pounds per 100 sq. feet of area again at the tail end of the rainy season. The timing of application is rather important so as to take advantage of the slight amount of rain to carry the material into the soil where it is most effective but to avoid the heavy downpours of the main rainy season which would cause excessive leaching consequently reducing the effectiveness of the treatment.

CMU is a new organic soil sterilant that has been recently introduced. This substance is highly effective for the control of grasses and certain other herbaceous plants. There are a few plants such as buckhorn plantain and morning glory that are not effectively controlled until higher rates of application are used. Where grasses are the principal problem from 25 to 40 pounds of CMU per acre is the recommended application. In extremely rainy areas it may be desirable to make two 25 pound applications spaced from several months to a year apart rather than relying solely on the 40 pound rate application. Again where certain hard-to-kill species such as plantain or morning glory may be present the addition of one to two pounds of 2,4-D per 100 gallons of spray would materially increase the total effectiveness of the treatment. In the application of CMU about 5 gallons of water should be used for each pound of CMU. CMU comes as a wettable powder and does not dissolve in water but merely suspends therein. Consequently sufficient water should be used as to reduce the handling problem. CMU presently costs in the neighborhood of $3.50 a pound so that sterilization with this material may run as high as $140.00 per acre. However, this 40 pounds of CMU is just as effective on a cost basis as sodium chlorate or chlorate borate mixtures, particularly where grasses are involved.

There are instances where maintenance of a grass cover particularly along road sides could materially

duce brush problems and problems with perennial noxious weeds such as tansy ragwort. In a case such as this selective chemical weed control should be practiced. In this case 2,4–D would be employed usually at a rate of approximately one pound of chemical per acre in sufficient water to get a thorough uniform coverage. This is rather a standard practice on Agricultural lands and could be put to good advantage in maintenance of proper cover in other situations.

Another case of selective weed control of interest to the forester is the control of alder and willow in new plantings of conifers. Again we find the weed killer 2,4–D to be the most practical solution to the problem. In this case a foliage application of the chemical is made in the spring employing one and one-half to two pounds of chemical per acre in either airplane application or application by ground equipment, depending upon the terrain. Very satisfactory relief of young timber has been obtained by this method with little or no injury to the young conifers. The selectivity here is dependent in part both on the tolerance to the 2,4–D coupled with the fact that the overstory of brush intercepts most of the spray with the conifer getting the lesser amount. Some bending of the leader has been noted in certain of the conifers but in time the plant seems to outgrow it. 2,4,5–T on the other hand if used singly or in combination with 2,4–D results in greater injury.

A summation of the weed control practices which we have discussed together with a elementary cost analysis will be found in table three.

FOREST RESEARCH

(Continued from page 12)

But I am confident that hardwoods will become more and more important in our forest economy and it is time we were learning more about them. Research on the silviculture and management as well as on the utilization of hardwoods should be expanded rapidly or industry will be asking for information that is nowhere available.

Let us consider for a moment the field of pulp and paper. As you know, the great expansion of this industry into the South during the last 20 years was primarily to use southern pine for Kraft paper and board (sulfate process). After the mills were well established and extensive forest holdings built up, it was found that in some places there was nearly as much hardwood as pine. The presence of these hardwoods and the increasing demands for various kinds and grades of paper have helped expand research into new pulping methods, new processes, etc., that point to a greater use of hardwoods. The trend is already under way; the demand for hardwood pulp is increasing; it accounted for 10 percent of the total pulpwood production in 1951, or double that of 1944; further increases can be expected.

Closely allied to the paper field is that of the synthetic board. You are all familiar with Masonite, the daddy of the hardboards. New processes have been developed for making both hard and soft board from pulp, from chips, and from plant wastes of sawdust, shavings, etc. Many new board mills have opened up in other parts of the country and we can look for some of them to locate in the Southeast in the next few years. Undoubtedly, they are going to use hardwoods, particularly if these hardwoods are sound, and readily available.

The wood chemical industry is only now getting under way, and we can look for a host of new materials to come from our southern hardwoods. These hardwoods are so varied that a multitude of new as well as synthetic materials should be made from them in the future.

We can anticipate that use of hardwoods for furniture, flooring, construction, pulp, etc., will continue or increase. You and I may see the time not far distant when the Southeast has another invasion of new industries, this time seeking hardwood supplies. I hope they will find us ready with our technology.

By working as a team with other public foresters and industry, we believe that our forests can produce sufficient timber, both of pine and hardwoods, to provide a more abundant economy in the coming age of cellulose. Over-all cooperation is needed in getting research results into practice.

KNIFE MARKS

(Continued from page 14)

a table of standards for knife marks per inch has been compiled; then, when a piece of material is held up to the light for inspection and the knife marks counted, something can be done about it if it shows 22 when 18 is the minimum necessary.

Regardless of the number of knives in the cutterhead or the revolutions per minute of the spindles the finish of the material is governed by the knife marks per inch. Therefore, whether there is one knife cutting at 7200 RPM or eight knives at 3600 RPM there is a maximum feed speed in each case. Circumstances control manufacturing conditions and the detail shop might operate most efficiently on high frequency, a furniture plant with comparatively short runs could use four or six knife equipment, while a high production moulding plant might use eight or ten knives but the same finished product in each case would have the same number of knife marks per inch if the minimum standard was employed.

Mention has been made of the information available on kiln drying. This includes methods for producing any degree of moisture required without affecting the texture of the stock. The result is that a set of standards has been recognized whereby, oak flooring must have a certain moisture content, possibly five or six percent, millwork a little higher, perhaps seven or eight percent. Studding, rafters, stringers, siding, all are checked for a certain moisture content to eliminate swelling or shrinking when applied to their particular use. If this is common practice, why cannot the finish on a piece of lumber be specified in knife marks per inch?

These sectional meetings of the Forest Products Research Society are particularly interesting as a place for discussion of any subject for the betterment of the woodworking industry. The suggestion of knife marks per inch as presented here is just another idea that would seem to have merit in this direction. Certainly, as previously mentioned, the individual mill owners and operators cannot be expected to do all the research for necessary data for such a standard but the Forest Products Research Society has a permanent committee to cover the machining of wood and it would seem that this would be a very valuable and interesting subject on which this committee could work. This could be done in conjunction with sectional groups, who really are the mill operators, and bring all classes of products and materials to a central clearing house. A questionnaire properly worded and properly presented might produce answers that would put concrete facts in the hands of such a committee.

Much is being written and said regarding the mechandising of goods in the future, and the prediction seems to be that competition will force the manufacturer to sell his present class of material at a lower price or to sell a better class material at the current price. It becomes vitally important to produce more of a better material by getting the greatest production possible from your machines and one way could be counting knife marks per inch.

LAMINATING

(Continued from page 21)

110 degrees F. This time and temperature is sufficient to give more than adequate polymerization of the resins now used, as well as the urea resins which have been used in the past. No curing room is available for the work after it leaves the clamps, but the products normally remain in the storage shed a minimum of three weeks before shipment.

Machining and Finishing

All the products made are of suitable size to be surfaced in a standard matcher in the planer mill. In the past no difficulty has been experienced in this machine work except in the surfacing of two inch dimension. On this work, the glue line makes a gap in the matcher side-head knives, resulting in an excessive amount of jointing and sharpening. Some of this difficulty can be diminished by using new knives which have not been softened by repeated jointing and grinding. On all of the laminated products except 2 x 4's there seems to be enough variation in glue line location as the work passes through the machine to prevent the formation of these gaps.

The laminated crossarms must be bored according to the specifications on the particular arm. Some types of arms must also receive a bevel. These operations on laminated arms are the same as if a solid arm were being produced.

Finally, many of the products, including all of the crossarms, must be pressure treated. Facilities are available at Diboll for treatment with pentachlorophenol or creosote. Crossarms for Western Electric are being penta treated.

Summary

The laminating system operated by Southern Pine Lumber Company is in full production making various laminated articles, most of which compete in today's market. The quality of the work produced in this plant is being found acceptable to all inspection agencies involved, although the cost of laminating by this process is not completely satisfactory. It is anticipated that the next step in development of this laminating plant will be to install end-jointing machinery so as to allow the use of short pieces instead of full length laminates. There is experimental work on this approach being done at the present time. A further development would be the use of a high frequency cure. There is a great need today for machinery designed specifically to produce these types of laminated products by "dielectric" heating.

Meanwhile these facilities are giving valuable service by providing information needed for future developments and Southern Pine Lumber Company is accomplishing the two primary objectives of this project: a product of the best quality available, and a utilization in the best possible manner of the lumber produced from the forest lands of the South.

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(Continued from page 32)

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TONERS

(Continued from page 43)

bleached wood it is necessary not only to have a clear lacquer which will not change color but the lacquer must also prevent discoloration of the wood itself. A lacquer which has proved suitable for use over bleached wood will be satisfactory over toner but there are many lacquers which will give good service over toners which would not possess the necessary protective powers for use over bleached wood.

The method of application of toners is of major importance in the maintenance of uniformity. If the toner is to be applied to give full opacity the spraying is relatively simple but care should be exercised to avoid too much overlapping at corners and edges since

this will tend to fill the pores and leave no place for the filler. Obviously this is even more important if the toner is to be applied at less than full hiding. It should always be remembered that the object is to obtain the desired color with a thin coat and to have this coat conform as closely as possible to the surface of the wood. All of the pores must be left open to receive and hold the filler so as to avoid a painted appearance.

There is a difference between applying a coat of toner and applying a finish coat of lacquer. Toners are usually used only on wood with open pores and the toner coat is applied directly to the wood. Lacquer has a tendency to be reluctant to wet the hard portions of the wood and to be absorbed by the softer parts. Thus we have the condition usually described as "crawling". Formulation of the lacquer can minimize this effect but it cannot be completely eliminated. This tendency can be overcome by misting the piece with a dry spray and then following with a coat just wet enough to avoid being dusty. Occasionally wood will vary so greatly in porosity from one spot to another that it will be necessary to first apply a light coat of toner, allow to dry, sand lightly to cut off the fibers which were raised from the porous spots and recoat with a wet coat.

Toners offer many advantages over bleaching. The finishing operation is easier and less costly, lower grades of wood can be used, greater resistance to color change on aging can be achieved, a vastly wider range of color is available, the system can be safely adapted to high speed forced-dry schedules and it can eliminate many uniforming problems. Some of the disadvantages of this type of finish lie in the fact that it is not practical to match the sparkling brilliance, clarity and depth of stained wood, it might require the exercise of more judgment on the part of the sprayer and it is not suitable for use on furniture made of mixed woods or close grained woods. Attempts to match bleached wood are likely to be disappointing to a critical observer. There are so many new and attractive effects possible through the use of toners and highly colored fillers that the finish should be promoted on its own merits rather than as an imitation of something.

CURRENT TRENDS

(Continued from page 45)

permits the raising of lacquer solids from 21–25% to 31–35% at the gun.

Successful application of lacquer by the hot spray method is largely a matter of a good unit for heating the lacquer. Several such units are now being offered by different manufacturers.

The lacquer is usually heated to around 160° F. and in most units this heating takes place just before the lacquer reaches the spray gun. This prevents heating of the lacquer in the supply pressure tank and the consequent possibility of nitrocellulose degradation.

The hot spray method offers certain savings because it requires less solvent per unit weight of solids deposited. Since the lacquer solvent is always lost by evaporation after the lacquer is deposited, the less solvent used the more economical is the operation.

In actual practice, one coat of lacquer in three may be saved by the user employing the hot spray technique, consequently a substantial saving in time and labor is achieved.

Hot spray lacquers are not basically different from conventional lacquers; the difference being only in somewhat slower solvent balance, higher solids and consequently higher velocity.

In conclusion, there is no doubt that, while nitrocellulose lacquer will remain an important quality finish for wood, we shall see more and more developments in the direction of synthetic finishes.

The coatings industry had its beginning by utilizing natural raw materials and paint and varnish formulation was an art and not a science. When the chemist first entered the industry progress was startling and has snowballed in a short space of time from improvements and refinements in the natural raw materials, through such developments as phenolic resins, low viscosity nitrocellulose, other cellulose ester and ether derivations, synthetic solvents, alkyd resins, synthetic pigments, nitrogen resins, vinyl resins, styrene butadiene resins, styrenated and vinylated alkyds, and a host of others.

It seems therefore, that synthetics show a trend towards becoming standard practice.

Discussion

Mr. Gibson when asked how the yellowing tendency could be minimized, stated that this tendency is primarily due to organic materials and can be minimized by the proper selection of lacquer ingredients. In answer to another member Mr. Gibson stated that the super type of synthetic is not yet on the market. When queried as to the fire resistant qualities of the super type synthetic he stated that, it would provide about one minute resistance to a burning cigarette. He further stated that it is totally resistant to boiling water. A final question was whether the super synthetic had any tendency to decrease checking in such articles as radio cabinets. Mr. Gibson pointed out that checking depends upon the characteristics of the wood and the type of finish does not control the degree of checking.

ALKYD RESIN

(Continued from page 46)

3–186. One type of material included under this specification requires an alkyd resin with a fungicidal material. The specifications call for a minimum of 12 percent resin solids, which in our opinion is considerably too low to provide the sealing qualtities demanded under the specification; however, by raising the alkyd solids up to about 20 to 25 per cent it is quite easy to meet the requirements of the specification, which demands a minimum of 45 per cent water repellency.

A large amount of hardboard is finished with baked enamels for use in tile board and imitation decorative tile. Here the resins must stand baking without too much color change, maintain both their color and gloss over long periods of time, provide surfaces which will not be easily marred by abrasion or by spillage of reactive substances, and also be capable of easy cleaning. By far the largest volume of material used on these surfaces are combinations of alkyd and amino baking enamels. The primer coat under such finishing schedules are frequently pure alkyd primers which are partially cured. The top coat of alkyd and amino enamel then is applied and the two coats baked together to provide satisfactory surface conditions. The type of alkyd used in these finishes is usually either a straight soya modified alkyd or a combination of soya and dehydrated castor oil modified alkyds.

Another use of baked enamel finishes on hardboard is in panel work and siding on cabinets. These finishes ordinarily are air drying enamel, having extreme color retention requirements. In air dry finishing of hardboard, the co-polymer or styrenated alkyd type resins recently have come into prominence as desirable vehicles. The co-polymer type resin with its excellent adhesion provides a vehicle with most desirable properties and characteristics for primer work. They give a finish which not only has excellent adhesion, but is easily sanded to give a smooth surface on which final coats of gloss enamel may be applied without danger of ghosting or loss of gloss. The very fast drying properties of this type resin make it possible to

apply a two coat system and pack and ship the same day.

Alkyd resins in emulsion form have been used as the factory protective coat on soft boards, but in the last few years they have decreased in popularity in favor of lower cost coatings. These lower cost coatings do not give the protection that an alkyd type coating would give, but apparently are sufficient to maintain satisfactory appearance until the board can reach the consumer.

The finishing of soft board requires a type of alkyd resin which has excellent sealing or non-penetrating qualties, and one which may be force dried at low temperatures or air dried to a hard, smooth surface. After the non-penetrating type prime coat is applied the board can be finished in a normal manner with air drying finishes. There have been some exterior applications of soft board and the finishing for this service is somewhat the same as the finishing of exterior lumber trim, which has been discussed. In other words, a non-penetrating prime coat is applied and then the alkyd top coats.

INCISING

(Continued from page 48)

due to incising. The most important source of variation in the strength properties of clear wood is specific gravity. An incised crossarm of high specific gravity is, of course, stronger than an unincised crossarm of low specific gravity.

A striking example of the incidental nature of the lowering of bending strength due to incising may be found in a statistical analysis of the data with no reference to pairing, i.e., as if each group were randomly selected from a population of Douglas fir crossarms. The difference between the averages is wholly lacking in significance, a fact which illustrates the danger of placing importance on small differences without the aid of statistical analysis.

An economic factor which involves time must be considered in judging the importance of the damage done by incising. An unincised, treated arm should not last as long in service as an incised, treated crossarm. After, say, 15 years of service under conditions favorable to decay, the loss in strength in the unincised arm due to decay will more than offset its initial strength which would be slightly greater than its perfectly matched, incised, treated mate with greater preservative penetration due to incising.

Summary and Conclusions

1. The ultimate load carrying capacity of crossarms is slightly, but significantly reduced as a result of incising when compared with matched, unincised crossarms. Tests on 16 well-matched pairs of crossarms, which represented material of various specific gravities, indicated that the average reduction in static bending strength due to moderate incising is in the neighborhood of four percent.

2. The slight reduction in bending strength which was detected by carefully matching an incised crossarm with an unincised arm from the same piece of wood is not practically significant when compared with the naturally great variations in strength between unmatched crossarms of any type due to the presence of defects as well as other natural variations in the wood.

3. Because of the fact that incising increases sidewise penetration of the preservative, matched pairs containing treated crossarms which are both incised and unincised should show equal strength after a period of service. The loss of strength due to the earlier decay of the unincised arm would offset the initially lower strength of the incised crossarm.

PETROLATUM

(Continued from page 49)

with uneven gloss. The reason for this is not understood but it is readily noticeable at normal sizing concentrations when paraffin wax is used.

It should be emphasized that there are many factors which affect the efficiency of sizing. Sizing efficiency is influenced, for example, by a variation in woods obtained from different locations, the responsiveness of different species of wood, and process differences which may occur at various hardboard plants. It is reasonable, therefore, to expect that there will be a relatively large variation in the amount of petrolatum required to give the same degree of sizing in different hardboard plants.

Cuts Power Costs

In all plant tests, no adverse effect was noted in plant operation or on equipment. In fact, certain phases of the operations are improved, for example, a 10% to 20% decrease of power used in operating the defibrators and refiners in the wet and semidry processes. This power decrease results from the lubricating effect of the hot petrolatum. Undoubtedly, this effect will increase the life of this equipment, but extended operations are required to determine how significant this may be. There is some evidence that when molten petrolatum is employed, fiber strength is increased, but this fact is not well established.

Preliminary work using petrolatum to size low density insulating board shows that adequate sizing can be obtained. Further work is required to find optimum conditions for the best strength and water absorption properties.

The problem of sizing kraft paper is somewhat more complex because of the varied paper products which are made and the necessity of introducing petrolatum at an earlier stage of the process than is customary for emulsion size. In addition, the pulp for kraft paper is subjected to a much more severe chemical cook than in the case of insulating board. In order to obtain satisfactory impregnation, it probably will be necessary to add the petrolatum to the digester or just after the cooked chips leave the digester, provided they are maintained hot during the initial refining stages.

Now Used Commercially

Petrolatum is now in commercial use for sizing hardboard and has proved to be satisfactory for all current hardboard processes. Liquid petrolatum could be used as a carrier for other materials to give special properties to the board. It may be possible to replace the alum now necessary in the wet and semidry processes by adding an aluminum soap or other water-insoluble metallic soap to the petrolatum. By this means, sizing properties might be improved and the strength-decreasing properties of the alum thus eliminated. It would be reasonable to expect a 20% to 30% increase of board strength by a successful process modification of this type.

Molten petrolatum has many untapped potentialities as a sizing agent for many wood pulp products. The financial advantage of using this method of sizing is providing the incentive for developing its use throughout the forest products industries.

MODERN CONSTRUCTION

(Continued from page 55)

under pressure over a long period of time.

Research could be done in combining various species for the best combination for appearance and the best structural properties.

Wrapping for waterproofing and weather protection in shipment is expensive and sometimes not wholly

effective. Perhaps a sprayed or brushed-on coating could be devised similar to the moth ball protection of naval vessels, for the protection of glulam in transit and erection. Highly effective transparent moisture seals, and fire retardant transparent coatings of good appearance would find good use in this field.

Last, but not least, the literature of timber construction should be unified and co-ordinated under one set of covers, without duplication or disagreement, for the use of designers throughout Canada. This alone can be one of the most important factors in the furtherance of timber as a construction material. Such unified data should include the necessary information as to connectors, bolted joints, sawn and glulam design formulas and unit stresses, information on nails and drift bolted and screwed connections, data on fire retardant and preservative treatments; data on glues and the effect on them of various industrial processes, and many other pertinent features of timber construction. In addition, there should be some standardization between manufacturers, of dimensions, nomenclature, and of combinations of grades which are used in design.

Much of this will be accomplished in the forthcoming National Building Code of Canada, and much of it is already available in the National Design Specification. Perhaps the point of origin for such unified literature should be a privately sponsored text book; perhaps it should be the result of work by an as yet, non-existent Canadian Institute of Timber Construction similar to that recently organized in the United States, or perhaps it can be done by a sub-group of the Forest Products Research Society. Whatever the source, the end result is badly needed and would act toward the betterment of the timber construction industry and the promotion of the use of wood products in construction.

Discussion

When queried as to whether glulam was a substitute for steel Mr. DeGrace stated that it could be considered as a satisfactory alternative in a number of cases.

In response to a question as to the amount of business conducted from 1945 to 1952 Mr. DeGrace estimated it to fall between 10- to 15-million dollars. He further stated it would be in the neighborhood of 6- to 8-million dollars for 1953.

Another member was informed that the only known failures of timber structures in Canada were due to incorrect interpretation of the design rather than to the failure of the structure itself.

Mr. DeGrace stated that timber structures in the form of keels and sterns are fabricated by his company.

A final question from the floor led Mr. DeGrace to state, that there is no difficulty in obtaining stock for glulam, and that either the mills or the prefabricating plant grade the material.

STRUCTURAL TRENDS

(Continued from page 58)

laminated material is being designed at around 2400# per square inch.

More and more, the general contractor on a construction job is recognizing the specialized field of timber assembly and erection and is insisting in a great number of cases that the fabricator follow through on the job and erect the material.

It has, of course, been impossible in this type of paper to tell of the technical advances in the design of bolted timber trusses, glued laminated beams and arches and all of the added knowledge that we have gained over the past years due to practical work and research in the laboratories. We can, however, summarize the trends as follows:

1. We have succeeded in the better classification of structural lumber. We are learning more and more about the grading of this lumber. This is important to the designer because he can design to a certain grade and obtain that grade in the final structure.
2. We are more and more pressure-treating lumber against decay, insects and, in a great number of cases, flameproofing the lumber.
3. More people are learning to design timber structures which means that there will be fewer and fewer cases where timber has failed due to the ignorance of the designer.
4. The Timber Engineering Company, through its laboratory, has tested full size timber trusses and expects to continue that work. As a result, we have the improved wedge fit split ring, which is a great improvement over the early split ring with the straight sides.
5. Glued laminated wood with its high stress value and the fact that it is fabricated from dry lumber is increasing in favor in a spectacular fashion. Glued laminated construction is not only coming ahead due to the inherent structural advantages, but also due to the very fine architectural effects that can be secured.
6. It would be an error not to include in this short discussion some mention of the short span split ring trusses that are being used by the thousands in modern schools, and in homes. The trussed rafter development has caught on and builders throughout the nation are beginning to realize that in the trussed rafter there is a saving for them and a faster way of putting on his roofs.

The writer can think of no trend that is not in the form of progress. Structural wood is being used more and more and this lumber is being prefabricated to a greater extent than ever before.

LUMBER GRADES

(Continued from page 59)

Generally speaking, the results of this study indicated that the lowest common grade of lumber in all five species yielded the most economical box. The difference in the price of lumber between the lowest grade and all higher grades was enough to offset the greater amount of waste and the additional labor required to cut out defective material from the boards of the lower grades. This information is shown in the following tabulation:

The cost figures shown in Table II were obtained in the following manner: The lumber cost was computed from the lumber prices in effect on March 15, 1951, at which time this study was being made. The total box cost was obtained by adding the following values: (a) the cost of lumber per box, (b) the cost of the time required for the cutting and nailing operations, (c) the cost of the nails, and (d) an overhead cost of 125 percent which was only applied to the time involved and not to the material involved.

A word of caution in the use of the results just presented should be added. It is apparent that although the boxes made from the lower grades require more lumber and more labor, the total cost per box was still less than that of boxes made from the higher grades for the reason explained previously. The finding of this study is an indication that the purchase of the lowest grade of lumber is economically sound but a complete change to such a practice may not always be feasible because:

a. An increase in the demand of the lower grade of lumber could affect

a change in the price of all grades of lumber that might make another grade a more economical purchase under different prices.

b. It would be difficult because of the numerous defects in the lowest grade of lumber to obtain a sufficient quantity of long length box parts needed for some larger containers.

c. There would not be a sufficient supply of the lowest grade of lumber available to meet such a demand.

In connection with the latter statement, I would like to bring to your attention the data showing the breakdown by percent of the common grades of lumber in some of these species. Table III.

TREATED PILING

(Continued from page 65)

tion of the Kansas City Viaduct demonstrated that after 47 years not the slightest sign of deterioration was evidenced in the creosoted piling.

Effect of Fire on Creosoted Material

Generally speaking, the creosote treatment of timber tends to reduce the fire hazard. A period of air seasoning following treatment and prior to use greatly reduces both combustibility and inflammability. The National Fire Prevention Association carried out tests which showed that it took 2½ times as long to ignite seasoned creosoted wood as compared with untreated wood. Under the same conditions, the untreated wood produced 1½ times as much burned material as the treated wood.

Many examples of the re-use of partially burned piling are known. Pressure creosoted piles and timbers, used in piers and docks, have definite slow burning characteristics regardless of the elevation of the tops. Creosoted piles do not burn off even after long periods of exposure. In designing piers and docks, it is recommended that more attention be given to fire walls, sprinkler systems and to adequate hose connections.

HEAD SPEED

(Continued from page 75)

obtained by using the higher head speed. Furthermore, since many of the machines used in testing of hardboards are of the variable head-speed type, the range of head speed concept will permit selecting an initial head speed so that the variations in head speed will be included within the allowable range throughout most of the testing period for a specimen.

The recommended span could be arbitrarily chosen between the limits 4 and 8 inches but should be specific since significant differences in average modulus of rupture values are obtained when 4- and 8-inch spans are used with a given head speed. From certain practical standpoints, the 6-inch span has merit. The 8-inch span for certain commercial boards yields excessive deflections. This is especially true when boards are tested at high moisture-content levels resulting from conditioning or soaking. The test data showed that a 4-inch span and a 2.00-inch-per-minute head-speed can be used without exceeding the critical rate of fiber strain; nevertheless, it is a borderline condition, therefore, should be avoided in a recommended procedure.

Conclusions

The test results clearly suggest the advisability of changing the static bending test procedure in the current tentative A.S.T.M. standard (D 1037-52T) "Evaluating the Properties of Fiber Building Boards" (1) to recommend the use of a 6-inch span and any head speed between 0.50 and 2.00 inches per minute for all commercial hardboards regardless of thickness or class of board. It is recognized that thicknesses over ¼-inch may produce different comparative relationships; however, if the critical rate of fiber strain is 0.33 inches per inch per minute for the thicker boards, a thickness of 0.99 inches, or approximately one inch, could be used with the 6-inch span and 2.00-inch-per-minute head-speed before the critical point is reached. This would indicate that the test procedure recommended here may be satisfactory for all commercial hardboards up to 1.00 inch in thickness.

Statistical Analysis

For the benefit of those readers interested in the statistical technique used in analyzing the test data, the following summary tables are included. Detailed calculation data are not included since the mechanics of determining the different components of variation can be found in any statistical reference.

Literature References

1. Anonymous. 1952. Tentative methods of test for evaluating the properties of fiber building boards. A.S.T.M. Designation: D 1037-52T.
2. Brown, H. P., Panshin, A. S., and Forsaith, C. C. 1952. Textbook of Wood Technology, Volume II, McGraw Hill Book Company, Inc.
3. Turner, H. D., Hohf, J. B., and Schwartz, S. L. 1948. Effect of some manufacturing variables on the properties of fiberboard prepared from milled Douglas-fir. Forest Products Research Society Proceedings 2:110–112.
4. Wilcox, Hugh. 1951. The effects of machine head speed and specimen span on modulus of rupture values obtained in static bending tests of a nominal $\frac{5}{32}$-inch Douglas-fir hardboard. TAPPI 34: pp. 314–316.
5. ——. 1953. The effects of pressing temperature and heat treatments on the relationships between head speed, span, and modulus of rupture of hardboard. TAPPI magazine (in press).
6. Youngquist, W. G. and Munthe, Bert P. 1948. The effect of a change in testing speed and span on the flexural strength of insulating and structural fiberboards and a proposed new method of test. U. S. Forest Products Laboratory Report R-1717.

PLASWOOD

(Continued from page 76)

Next, the chips enter another pipeline and are blown into storage bins. En route, small, unwanted particles drop through a screen set in the base of the pipeline.

When required, the chips are shot back through another pipeline to the treating bay. There they pass under strong magnets which attract any metallic particle that might still be lodged among the chips.

Each batch is carefully weighed and the required amount of resin and moisture-repelling additive is sprayed on the particles. A catalyst is sometimes added to prevent the liquid resin from crystallizing. As a rule, this is necessary only occasionally, and then usually in summer. Through experience the mill has found the most satisfactory urea glue bond is one prepared from a formula developed in its own laboratory, made in the plant

Next, the treated chips are spread in trays which are inserted in multiples of ten into the hot-press and subjected to intense heat and pressure for varying time cycles up to seven minutes. The desired panel thickness is governed by a device attached to the press. On emerging from the press, the boards are weighed to make certain that they possess the proper density and then trimmed to the standard 4′ x 8′ size. Its resistance to indentation is exceptionally good—on a par, in fact, with Birch. It holds nails more firmly than many softwoods. Approximately 50 pounds are required to draw a 6D nail driven through a ⅜" board. As for screw holding, it compares favorably with plywood.

How to Use It

Plaswood may be nailed, sawn or machined the same as lumber or plywood. But the higher percentage of resin used in bonding results in the board being more abrasive to tools than lumber or plywood. On production runs, Tungsten-carbide-tipped saws and shaper heads give the best satisfaction.

Plaswood is shipped from the mill at 6% to 8% moisture content, which is ideal for furniture manufacturing. Whenever Plaswood is to be used for underlay or sheathing, it should be stacked to allow for expansion before use and applied with 1/8" gap between sheets.

In most Canadian areas, Plaswood stabilizes at 10 to 12% moisture content. Standard plant control tests show 3.2% expansion in thickness after immersion in cold water.

The urea-formaldehyde resin with which Plaswood is impregnated results in a definitely higher ignition point and a higher flame resistance than ordinary wood. Its K factor is approximately 1.0.

Plaswood is made in four thicknesses: 3/8", 1/2", 5/8" and 3/4". The 1/2" and 5/8" boards particularly are being used extensively for many purposes. When the new, high-density board first appeared on the market in 1950, it was used almost entirely as floor underlay. At that time as much as 75% of the mill's output was exported to the United States. Now, with last year's production standing at 6 million square feet, the Canadian market absorbed more than 95% of the output. The proportion used for underlay has dropped to 40%.

The board has found ever-widening acceptance for other applications. These are principally sheathing, partitioning, and furniture corestock, and lately as exterior sheathing.

Several chrome furniture manufacturers use Plaswood almost exclusively as corestock. Firms using Plaswood as corestock have adapted certain standard tested methods of application to suit their own requirements, based on the general suggestions made by Trafalgar Mills. This applies also to the manufacturers of veneered furniture.

Plaswood is readily adaptable as a laminated product in thicknesses up to two inches or whatever press openings will permit. The board may also be easily faced with tempered or untempered hardboard faces, wood veneers, plastic laminates, or virtually any other finished surface.

Plaswood is less hygroscopic than wood, but, like all wood and wood fibre products, it has a tendency to expand if subjected to moisture or high humidity.

Trafalgar Mills has already had some success in developing a foam resin which, it is believed, may reduce production costs and provide an even better bond than the one used currently. Also, on an experimental basis, a new, low-density sheathing board, which is much stronger in bending strength and far more stable dimensionally than the original sheathing board has been manufactured.

Discussion

This paper was presented by Mr. T. Ortiz of the same company. Mr. Ortiz, when asked what industries were the consumers of his product, stated that the building trade took 60%, the furniture trade 25%, and the remaining 15% went primarily to the small home owner.

PULPWOOD

(Continued from page 80)

ft. is justified. Recent introduction of an effective mechanical log debarker has stimulated interest in the conversion of sawmill waste into chips. With a recovery of .43 cords per 1000 bd. ft. lumber talley being experienced by large band sawmills in the South, more information concerning the cost of transportation and the cost of mechanically loading and unloading chips into these box cars should become available.

In the Lake States gondola cars and renovated flat cars haul an average of 20 cords of 8 ft. wood per car. With the exception of the special pulpwood car with door-like sides for the dumping of wood, pulpwood cars in the Northeast are constructed with sides which will not permit mechanical unloading. These cars will hold from 16 to 25 cords of 4 ft. pulpwood.

The South has developed an all steel open-sided rack car which will carry up to 26 cords of green 5 ft. pulpwood. Because these cars can be mechanically loaded and unloaded they are being tested for possible use in the Northeast.

Of interest is the large fleet of truck-trailer units employed by one company in the South to supplement a railroad system that is unable to supply the mill with a sufficient volume of pulpwood at the desired transportation cost. Complete with dispatcher and radio communication, each unit is designed so an empty trailer crib can be placed on its own legs while the rear wheels and bogie are removed for placement beneath a loaded crib. After the tractor has fastened onto the loaded trailer, the legs are retracted and the entire trucking unit is ready for a trip to the mill. (Figure No. 18).

Conclusion

In restricting the subject of material handling to the minimum number of required steps of piling, skidding, and loading and unloading trucks or sleighs, 32–38% of the total cost of production required to deposit a cord of pulpwood at an unloading point is absorbed by material handling. On operations requiring a number of pulpwood rehandlings and when all handlings are included up to the point of placing wood on a mill woodyard conveyor, this percent of the total cost of production becomes quite large. In view of this fact, consideration of improved material handling methods are of utmost interest and importance to the Pulpwood Industry. The growing shortage of manpower, the increased cost of labor, and the demand for quantities of pulpwood exceeding all previous records will necessitate the replacement of manpower with machine power in a number of operational steps required in the production of pulpwood.

WOOD DEFINITIONS

Angiosperms: The botanical name for a group of plants that includes the so-called hardwoods; literally the word means "having the seeds enclosed." Terms commonly applied to trees belonging to the angiosperm group: hardwoods, deciduous trees, porous woods, broad-leaved trees.

Cambium: The layer of tissue just beneath the bark of the tree from which the new wood and bark cells of each year's growth develop. On the inner side of the cambium the typical wood cells, springwood and summerwood, are formed. On the outer side of the cambium the phloem, or bast, is formed.

Diffuse-porous Woods: Certain hardwoods in which the pores tend to be uniform in size and distribution throughout each annual ring or to decrease in size slightly and gradually toward the outer border of the ring. Compare "Ring-porous Woods."

Equilibrium Moisture Content: The moisture content at which wood neither gains nor loses water when surrounded by air at a given relative humidity and temperature.

Hemicellulose: A polysaccharide or a mixture of polysaccharides that is associated with cellulose soluble in alkali, and that is easily hydrolyzed by dilute acids.—From U. S. Forest Products Laboratory.

Abstracts

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiber board and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

FOREST PRODUCTS AND UTILIZATION ABSTRACTS are published quarterly by the Commonwealth Agricultural Bureaux of London, England, as a separate reprint of decimal sections 3, 7, and 8 of Forestry Abstracts, for the facility of those interested chiefly in the field of wood utilization. The abstracts are prepared by the Commonwealth Forestry Bureau, Oxford, England, and the utilization section contains about 1,200 titles and abstracts per year from literature in some 30 languages and covers all aspects of forest utilization from cutting and extraction through marketing, mechanical, and chemical processing to minor forest products. FPRS members interested in obtaining the complete issues of Forest Products and Utilization Abstracts should communicate with the Secretary of the Society.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

Wood and Its Properties

Williams, E. J. Applications of component analysis to the study of properties of timber. *Aust. J. appl. Sci.* 3 (2), 1952 (101–18). 7 refs. P.R.

Describes how the different components of variability in properties of timber may be distinguished and their magnitude assessed. The variation that occurs between different trees can be separated from that within the tree, and that between species from that between different trees of the same species. The need is indicated for this type of analysis in arriving at valid standard errors for average of properties and in making significance tests of differences among experimental results. Component analysis is also important as a guide to sampling, and methods of improving the efficiency of sampling by its use are described. *From author's summary.* [Cf. *For. Abstr.* 14 (Nos. 809, 814).] [For. Prod. Util. Abs. V. 14, No. 1]

Young, H. E. Differential time of change from earlywood to latewood along the bole of young Loblolly Pine trees. *J. For.* 50 (8), 1952 (614–5). 5 refs.

Four 14- and 15-year-old *Pinus taeda* trees were felled, and sections removed at ground level, breast height, 50%, 65%, and 80% of total height. Measurements were made of the early and late wood of each annual ring on the average radius of each section. For the current year, the % of late wood decreases from the ground level to the tip. The inception of late wood seems to begin at ground level in June and gradually appears up the bole until it occurs near the tip in early September. At any given level on the stem, the % of late wood in the annual ring increases from the pith towards the cambium. It is suggested that since the terms spring and summer wood or early and late wood have little meaning, they should be replaced by the terms region of large cell formation and region of small cell formation. *From author's summary.* [For. Prod. Util. Abs. V. 14, No. 1]

Entrican, A. R., Ward, W. C., and Reid, J. S. The physical and mechanical properties of the principal indigenous woods of New Zealand. New Zealand Forest Service, Wellington. 1951. pp. 83 + 1 photo. 22 refs.

Presents the results of more than 40,000 tests on wood of 9 softwood and 16 hardwood species. Data of 23 well known commercial species from other countries are given for purposes of comparison. [For. Prod. Util. Abs. V. 14, No. 1]

Moisture content changes in seasoned lumber in storage and transit. *Bull. For. Br. Can.* No. 102, 1952. pp. 16 + 3 photos.

Summarizes the results of studies made and published between 1931 and 1937 at the Vancouver Forest Products Laboratory and now out of print, and gives some additional data derived from subsequent research. (1) Change in moisture content of lumber in storage. (2) Change in moisture equilibrium of kiln-dried and air-dried lumber. (3) Change in moisture content of lumber when shipped by rail. (4) Change in moisture content of lumber during ocean shipment. (5) Absorption of moisture by lumber in British Columbia. [For. Prod. Util. Abs. V. 14, No. 1]

Kollmann, F. Uber die Abhängigkeit einiger mechanischer Eigenschaften der Holzer von der Zeit, von Kerben und von der Temperatur. Erste Mitteilung: Der Einfluss der Zeit auf die mechanischen Eigenschaften der Holzer. [Dependence of some mechanical properties upon time [test duration], notches and temperature. 1. Effect of time upon the mechanical properties of wood.] *Holz Roh- u. Werkstoff* 10 (5), 1952 (187–97). 25 refs. [G.] P.R.

Analysis of the results of mechanical strength tests on wood, made by the author and by other investigators, leads to the conclusion that owing to the plastic properties of wood, the rupture stresses can have real significance only if the time factor is stated. The quicker the stresses are generated, the less likely are relaxation and plastic flow in high-polymer substances such as wood. If the plasticity of wood is related to the sliding of micelles, then an increase of internal 'lubrication' (by water, other plasticizers, or by temperature rise) can be made use of in moulding processes. The plastic properties are responsible for the mechanical hysteresis and, consequently, the damping capacity of wood. [For. Prod. Util. Abs. V. 14, No. 1]

Campbell, W. G., and McDonald, I. R. C. The chemistry of the wood cell wall. Part I. The delignification of Beech and Spruce woods by sodium chlorite in buffered aqueous solution. *J. chem. Soc.* July, 1952 (2644–50). [Forest Products Research Laboratory, Princes Risborough.] O.R.S.

In the delignification of *Fagus sylvatica* and *Picea sitchensis* by aqueous solutions of sodium chlorite, buffered at pH 6·3 at 50° and 70°, some 90% of the acid lignin can be removed from each wood without significant loss of polysaccharide, but attempts to delignify the wood residues further cause appreciable loss. Chemical analysis of some partly delignified residues, containing 5–90% of the original acid lignin, indicated that there was retained in the wood residue a modification of lignin which is not determined by the 72% sulphuric-acid method. The total percentage of poly-

saccharide present in each wood is considerably less than 100 — x, where x is the acid-lignin content of the original wood; therefore it may be inferred that x does not equal the total lignin content of the wood. Any determination of 'holocellulose' based on a yield equivalent to the formula 100 — x is erroneous because even though the acid-lignin content may be small there is also present a large proportion of 'modified lignin'. [For. Prod. Util. Abs. V. 14, No. 1]

tevens, G. de, and Nord, F. F. Investigations on lignin and lignification. IX. The relationship between the action of brown rot fungi, cellulose degradation and lignin composition in bagasse. *J. Amer. chem. Soc.* 74 (13), 1952 (3326–8). 13 refs. O.R.S.

Discusses the comparative effect on the cellulose, and the lignins liberated by, the softwood fungi *Poria vaillantii* and *Lentinus lepideus,* and the hardwood fungi *Daedalea quercina* and *Polyporus sulphureus.* [For. Prod. Util. Abs. V. 14, No. 1]

Jones, J. K. N., and Wise, L. E. The hemicelluloses present in Aspen wood *(Populus tremuloides).* Part I. *J. chem. Soc.* July, 1952 (2750–6). [Institute of Paper Chemistry, Appleton, Wis.] O.R.S.

Hydrolysis of extractive-free Aspen sawdust yields *l*-rhamnose, *l*-arabinose, *d*-xylose, *d*-galactose, xylobiose, xylotriose, 4-methyl-*d*-glucuronic acid and several oligosaccharides containing uronic acids. The action of periodate on the sawdust and on isolated hemicellulose has been examined. The results are discussed. *Authors' summary.* [For. Prod. Util. Abs. V. 14, No. 1]

The ignition temperatures of certain pulps and other wood components. M. A. Buchanan (Inst. Paper Chem., Appleton, Wis.) Tappi 35, 209–11 (1952).

By using a method developed by Van Kleeck of the Forest Products Lab., ignition temps. were detd. in an app. having a temp. rise of 4.5–7° per min. The following data on ignition temp. are given: Lignin samples: Meadol 185; Scholler lignin 180; Indulin A 185; Willstatter spruce lignin 180; Ca lignosulfonate 235. Wood and components: Slash pine (I) wood meal (27.5% lignin) 230; I semichem. pulp (27.2% lignin) 215; Chlorited I semichem. pulp (4.2% lignin) 250; I kraft pulp (3.4% lignin) 260; I a-cellulose 260; aspen hemicellulose 180; spruce hemicellulose 170. Pulps: spruce groundwood 210; aspen semichem. 215; bleached sulfit 265; unbleached sulfite 260; unbleached kraft 260; bleached kraft 260; cotton linters 275; and unbleached manila hemp 240°. F. T. Ratliff [Chem. Abs. V. 46, No. 15]

The effect of temperature on the elasticity and strength of wood. F. Roh– u. Werkstoff. 10, 269 (1952). Kollmann (Reinbek, Ger.). Holz

Elastic modulus and tensile, compressive, and bending strength decrease with increasing temp. Generally, the effect increased with H_2O content. Duration of heating may also have an effect; thus the bending modulus at 70°, after showing an initial drop, slowly recovers. Temp. has a variable effect on toughness. The ability of wood to absorb impact energy at any temp. cannot be predicted from its behavior at another temp. H. Tarkow [Chem. Abs. V. 46, No. 22]

Chemical effects of weathering on wood in normal and polluted atmospheres. *Rep For. Prod. Res. Bd., Lond. 1950,* 1951 (47–8).

The chemical effects and the resulting decrease in mechanical strength, of radiations in the visible part of the spectrum, and ultra-violet and thermal radiations in normal weathering are described, with the accelerated effect produced by SO_2, alone or with NH_3 in polluted atmospheres. Protection of wood by a coating of heat-resisting impervious paint is suggested. [For. Prod. Util. Abs., V. 13, No. 5]

Timber Harvesting and Lumber Manufacturing

Justsuk, E. Schwedische Entrindungsmaschinen. [Swedish barking machines.] *Holz Roh- u. Kerkstoff* 10 (6), 1952 (229–38). 5 refs. [G.g.] P.R.

An illustrated description of Swedish machines for barking logs at sawmills. Three pre-treatment plants (steam, water, or steam-and-water treatment), 5 cutting barkers, and 8 friction barkers are illustrated and described in detail. The output of the Andersson's pneumatic-friction-principle barker is tabulated for different log diameters and two feeds. The total cost of barking (in öre/cu.ft.) is: 2·04 for cutting barkers, 1·88 for friction (log against log), and 1·28 for friction (tool against log) barkers. [For. Prod. Util. Abs. V. 14, No. 1]

Band saw setting—an interesting new machine. *Timb. Tr. J.* 202 (3957), 1952 (296).

The 'Lasso-Rapid' bandsaw-setting machine has been introduced to the U.K. market by C. D. Monninger Ltd., Tottenham, London, N.15. The equipment operates a pair of rollers, each with a wavy-shaped surface, which press the bandsaw's toothed edge so as to give a wavy sawing line. The teeth are thus set in a series following the line of the waves, instead of each tooth being individually set. The method is claimed to give a smoother and more even cutting surface. [For. Prod. Util. Abs. V. 14, No. 1]

Glues and Gluing

Knight, R. A. G. Adhesives for wood. Chapman and Hall Ltd., London. 1952. pp. xi + 242 + 9 plates. Many refs. (Monographs on Metallic and other materials published under the authority of the Royal Aeronautical Society, Vol. III.) Price 25*s*. [Forest Products Research Laboratory, Princes Risborough.] P.R.

Contains sections on: glues of natural origin; synthetic-resin adhesives; factors in gluing technique; conditions under which adhesives are used; testing adhesives; classification of glues according to their durability; the bonding of wood to other materials; and a glossary of special terms. There are numerous graphs and tables and a list of references for each chapter. [For. Prod. Util. Abs. V. 14, No. 1]

Petz, A. Holzverfarbungen bei Verleimung mit Kunstharzen. [Staining of wood during gluing with synthetic resins.] *Holztechnik* 32 (7), 1952 (368). 2 refs. [G.] P.R.

Staining caused by Fe in wood occurs very rarely in synthetic-resin gluing, and can be removed by washing with K oxalate. A reddish-brown colour sometimes observed when using the urea-resin glues with different cold hardeners has been found to be caused by excess of hardeners; these stains are first treated with ca. 12% NH_4OH, then with K oxalate, and finally rinsed with warm water. Both oxalic acid and K oxalate, when used in higher concentrations, can themselves be a cause of brown stains, hence if stains are not removable by low concentrations of these, H_2O_2 should be used instead. [For. Prod. Util. Abs. V. 14, No. 1]

Stevens, W. C., and Turner, N. Modifications of a method of improving the steam bending properties of certain timbers. *Wood* 17 (8), 1952 (296–9). [Forest Products Research Laboratory, Princes Risborough.]

Gluing a thin lamina of wood with good bending properties to the face which when bent will have the maximum compressive strain [cf. *For. Abstr.* 12 (No. 457); 13 (No. 4265)] is only possible when a supply of

good bending wood is available, and the mixture of species may be objectionable aesthetically. In the modified method the supporting layer, which need not necessarily be a good bending wood, is arranged so that its grain is at right angles to that of the thicker piece, then glued, steamed and bent in the normal way. Successful results were obtained with a number of tropical hardwoods, including *Cistanthera papaverifera, Berlinia* sp., *Gossweilerodendron balsamiferum, Mitragyna stipulosa* and *Khaya ivorensis*. It was not found necessary to dry the assemblies to be glued to a uniform moisture content not exceeding 20%; instead, drying only the surface layers to a depth of about ⅛ in. to this figure gave satisfactory adhesion. The bends made in this test series had a radius of 6½ in. and each piece was 3 ft. 3⅜ in. long, 2¼ in. wide and 1 in. thick excluding the supporting layer. Results are discussed and illustrated with some photographs. The thickness of the supporting layer needed to produce bends free from buckling on the face or wrinkling at the edges depended on the bending properties of the material to which it was glued; buckling in the concave face of *Guarea thompsonii,* a fairly good bending species, could be prevented by using a cross-banded layer $\frac{1}{16}$ in. thick of the same species, while *Khaya ivorensis,* a poor bending wood, needed five $\frac{1}{16}$-in. *K. ivorensis* veneers. It is not possible to calculate from existing bending data the minimum thickness of supporting layer to be used for a particular type of bend, and preliminary tests must generally be made. In tests on 1-in. specimens of *Guarea cedrata* supported by a $\frac{1}{16}$-in. veneer of *K. ivorensis* the limiting radius of curvature was reduced from 9 to 5 in. It is probable that bends produced from a good bending timber, where this is available, will be cheaper than those made by the glued assembly method. Further information on the new method may be obtained from the Director of the Forest Products Research Laboratory. [For. Prod. Util. Abs. V. 14, No. 1]

Horioka, K., and Furuse, M. Studies on plywood. Report No. 1. On water-proof plywood glued with cold-setting phenol-formaldehyde resin. *Bull. For. Exp. Sta. Meguro, Tokyo* No. 51, 1951 (33–60). 7 refs. [Jap.e.]

Two brands of commercial phenol-formaldehyde cold-setting resin were used with β-naphthalene-sulphonic acid as hardener, and the optimum values of hardener addition and temperature were determined. Formulae were derived for (1) relation between the optimum temperature and the time of treatment following cold pressing for 24 hours at 20° C.; and (2) relation between the heating temperature (range 30–60°) and the boiling-test strength. Best results were obtained for veneers with 10% moisture content, and for glue mixes containing 70–76% of resin. The amount of glue used was 35–40 g./sq. ft. [385–440 g./sq. m.]. Diatomaceous earth proved to be a better extender than wheat flour. The adhesion rates for 5 temperatures were evaluated, from an empirical formula, for one of the two resins, and it was found that these rates (in arbitrary units) were: 20°, 0·0297; 30°, 0·671; 40°, 1·000; 60°, 1·729, and 80°, 2·045. Hence, the lowest temperature to be used in industry is 30°. [For. Prod. Util. Abs. V. 14, No. 1]

Lombardi, G. Der zusammengesetzte Druckstab aus Holz. [Composite pressure strut made of wood.] *Schweizerische Bauzeitung, Zürich* 69 (22), 1951 (301–3). [G.] *Abstr.* in *Index aeronauticus* 7 (11), 1951 (167–8). P.O.

The object of this report is to consider the problem of analysing mathematically a continuous union of several pieces of wood and to obtain formulae which determine the properties of such pressure struts and their binding material. The binding material is assumed to be distributed uniformly along the whole length of the strut. Since no further assumption regarding the method of binding is required, the results are applicable to every kind of bond. The case of 3 laminations is worked out in detail, assuming a symmetrical shape. A strut with 5 laminations can be dealt with in a similar manner. The case of 4 laminations is a special case of this. In a similar fashion, the formula for 3 laminations can be used for 2 laminations. The report concludes with a comparison between the two-lamination strut and a solid strut, where it is shown that the formulae obtained are in good agreement with the general Eugesser formula by Stussi for a solid strut. [For. Prod. Util. Abs. V. 14, No. 1]

Seasoning and Preservation

Finholt, R. W., Weeks, M., and Hathaway, C. New theory on wood preservation. *Industr. Engng. Chem.* 44 (1), 1952 (101–5). 10 refs. P.R.

Comparative toxicity tests were made on a series of normal alcohols and amines in an aqueous medium (malt/agar) and in wood (Leutritz soil-block method), using *Lentinus lepideus* as the test fungus. Results support the authors' hypothesis that fungitoxic materials fall into two classes differing in mode of action: (1) 'Interior fungitoxics', acting inside the fungus cell. For these, solubility in water is one requirement, but molecular size is also shown to be concerned: the active materials are limited to a maximum carbon chain length of ca. 12, larger molecules being apparently unable to pass through the cell wall of the hyphae. (2) 'Exterior fungitoxics', acting outside the fungus cell, possibly by denaturing the hydrolases excreted by the hyphae, and so preventing rot in wood, though ineffective in malt/agar where no hydrolytic activity outside the cell is necessary. These may be soluble or insoluble in water and are not limited in activity by their chain length. [For. Prod. Util. Abs. V. 14, No. 1]

Fritz, C. W. Brown stain in Pine sapwood caused by *Cytospora* sp. *Canad. J. Bot.* 30 (4), 1952 (349–59 + 9 photos). 1 ref. P.R.

A fungus isolated from naturally brown-stained Red Pine sapwood was found to produce characteristic chocolate-brown stain in sterilized Red Pine sapwood in culture; it is identified as a species of *Cytospora.* The fungus develops in the ray parenchyma, may proliferate in the tracheids, but penetrates the walls only through the pits. A technique is described for producing brown stain in culture in sticks of the size required for static bending and toughness tests. Two series of sticks were subjected to each test; the samples used were end-matched sticks in groups of three, which provided a green control, sterilized control, and specimen stained in culture by *Cytospora* sp. The results showed some variation in the relative strength of samples in different groups, but a statistical analysis indicated that the effect of *Cytospora* sp. on both bending strength and toughness is negligible. *Author's summary.* [For. Prod. Util. Abs. V. 14, No. 1]

Scheffer, T. C., and Englerth, G. H. Decay resistance of second-growth Douglas-fir. *J. For.* 50 (6), 1952 (439–42). 13 refs.

Graveyard tests showed that the decay resistance of second-growth Douglas Fir wood from a number of sites was for the most part moderate, but not inferior to that of virgin-growth wood. The larger differences in resistance appeared to be of genetic origin. [For. Prod. Util. Abs. V. 14, No. 1]

Wood Construction

A quick-assembly roof. *Wood* 17 (3), 1952 (316–7).

The 'punt' system of roofing, designed by Ove Arup and partners, consists of a series of prefabricated boxes or 'punts' made of plywood sides 16 in. deep, a plywood top 3 ft. 4 in. wide to form the roof, and a perforated hardboard ceiling underneath. The boxes are stiffened by light timbers glued to the sides and by timber strips in the corners. A 1-in. blanket of glass wool fixed to the underside of the roof plywood gives a U value slightly better than 0·20. The punts are placed at 6 ft. 8 in. centres on their supports, which leaves a space of 3 ft. 4 in. between adjacent punts. Each space is filled in with a prefabricated plywood panel, resting on ledges provided on the sides of the punts. The units can be made to any reasonable size, but are at present made to fit a 3 ft. 4 in. module, being 3 ft. 4 in. wide and in length increasing by intervals of 3 ft. 4 in. from 10 ft. 0 in. to 23 ft. 4 in. The punts can be supported on any normal construction, but a specially designed timber frame has been evolved, consisting of plywood box beams with ledges bonded on either side to support the punts. The roofing system is illustrated with photographs, sectional plans, elevations and sections. [For. Prod. Util. Abs. V. 14, No. 1]

Wood Finishing

Fire prevention in the finishing shop
W. A. Scott
Canadian Paint and Varnish Magazine. Canada, Vol. 26 No. 10, October 1952, pp. 42, 44, 46, 3 illus.

Three essentials in fire prevention are the elimination of ignition, the limitation of the quantity of materials and the control of the propagation of flame. A possible source of ignition in the finishing room is electrical equipment which is of unsuitable design. Low pressure steam equipment should be designed and maintained so that waste material does not accumulate on it and become heated to ignition. Care should also be taken to prevent overheating in the bearings of fans, etc., a possible precaution in this respect being the use of sealed, lubricated bearings. Belts, either flat or V, are not desirable in finishing areas because of the danger of static electricity. Apparatus should preferably be directly connected to motors, or be chain driven.

Cleanliness and good housekeeping are extremely important in preventing the spread of fire by the ignition of waste or spare material. Thinners or benzol, however, should never be used for removing residues as they increase the danger of fire, particularly if steel scrapers are used to remove loosened residue. Special materials can be sprayed on equipment, walls, etc., to prevent the adhesion of particles of finish to metal-work, and strong alkaline solutions generally suffice for cleaning. [Tech. Bul. F.D.C., V. 3, No. 13]

The technique of spray painting, A. L. Phillips
Organic Finishing, U.S.A., Vol. 13 No. 8, August 1952, pp. 14–9, illus.

Directions are given on the correct method of holding and adjusting a spray gun. Some typical faults are shown diagrammatically and their cause and correction are tabulated. It is important to give the gun daily maintenance and holes should not be cleaned with wire or any material that has an abrasive action. The air supplied to the gun should be as clean as possible. Cleaning devices incorporated in the gun are frequently only necessary because the inlet air is drawn from a dusty part of the plant.

In discussing spraying pressures it is noted that at 8 in. from the gun, a 5 lb. atomizing pressure is equal to a 20 mph wind. At very high pressures the paint bounces off the target and gives rise to a faulty finish and an unnecessary loss of paint. The pressure should be sufficient to atomize the paint and produce a perfect pattern at a distance of 8 in. from the nozzle. The correct material pressure is obtained when a stream of paint starts to arc to the floor 3 ft. from the nozzle of the gun when the atomizing air is cut off. When material of a higher viscosity is used a nozzle with a larger orifice may give better results than a higher pressure.

An uneven coating will be deposited if the operator sways his body during spraying, or moves his wrist. There should be no wrist movement whatever as is illustrated by the action of automatic spraying set-ups. [Tech. Bul. F.D.C., V. 3, No. 13]

Airless atomization spraying technique
Bede Products Co.
Industrial Finishing, U.S.A., Vol. 28 No. 12, October 1952, pp. 102–3

Hydraulic pressure combined with high heat is used to effect spraying with this technique. A steady fluid pressure of 300–600 lb. per sq. in. is maintained by a special pump and the material is heated to 160°–220° F. by an electric heater.

The heat serves to lower the viscosity of the fluid and raise the vapour pressure, while the high pressure prevents actual 'boiling' of the solvents until the finish phases through the nozzle of the spray gun. At this point the release of vapour pressure serves to break up the particles of finish. In this way the solvent present serves as an atomizing agent, although sufficient solvent remains in the finish to permit a good flow out.

Advantages claimed for the system are reduced overspray, less air exhaust requirements, absence of spray rebound, close control of viscosity and film thickness and simple operation. [Tech. Bul. F.D.C., V. 3, No. 13]

Finishes for wood: compatibility of materials
Woodworking, Vol. 56 No. 705, August 1952, pp. 154–5

When renovating furniture it is sometimes desired to apply a finish over an existing one without the expense of both stripping and complete re-finishing. In these cases it is necessary to know the nature of the finish previously used and a quick method of testing in the shop is suggested. If the finish is scraped with a razor blade, the shavings, if from varnish, are slightly yellow, and are detached in one piece which is elastic. French polish comes away as a powder, while cellulose may give either powder or a shaving lacking elasticity and easily crumbled, the damaged edge being of whitish appearance.

Solvents may also be used for testing the finish. Methylated spirit affects French polish and spirit varnish, although, for old finishes, it may require some time in contact. Cellulose thinners attack cellulose surfaces and also some synthetics. Methylated spirit has no action on cellulose finishes.

Referring to the application of the new coating, varnish may be used on varnish, French polish, and cellulose. Cellulose lacquer is satisfactory over French polish, but should not be sprayed over spirit varnish as the latter may contain ingredients vulnerable to the solvents. The use of French polish over cellulose lacquer is not recommended, as adhesion may be poor, If varnish is applied over a cellulose coating, the latter must be completely dry so that solvent after-effects may be avoided. Further the cellulose surface should not be too flatted, if it is pigmented, as removal of pigment near the surface may cause irregularity in appearance. [Tech. Bul. F.D.C., V. 3, No. 13]

Wood Working Equipment

Roderick chalk sharpener,
E. Alexander and Co. Ltd.

The Maker-Up, Vol. 27 No. 3, September 1952, p. 217, 1 illus.

The sharpener allows for more economical use of marking chalk. Chalk dust falls into a box which can be emptied periodically. [Tech. Bul. F.D.C., V. 3, No. 13]

Quality Control

ASTM manual on quality control of materials. *Special Technical Publication, American Society for Testing Materials, Philadelphia, Pa.* No. 15–C, 1951. pp. xii + 127. 8 refs. P.R.

A manual of methods for the statistical analysis and presentation of data, replacing the earlier ASTM manual on Presentation of Data (1933 and 1935), in three parts: (1) Presentation of data—frequency distributions, simple statistical measures, and the concise presentation of the essential information contained in a single set of n observations. (2) Presenting the $\pm$ limits of uncertainty of an observed average. (3) The control-chart method of analysis and presentation of data, with examples. [Cf. *For. Abstr.* 14 (Nos. 601, 814).] [For. Prod. Util. Abs. V. 14, No. 1]

Ralston, J. M., and Klein, M. Methods of checking wood and chip quality. *Tappi* 35 (7), 1952 (294–7). P.R.

Describes the procedure for making wood quality counts adopted by an American pulp mill for determining trend in the quality of new receipts and for explaining variations in operations. Each log in a sample is classified according to definitions set up for each of the various types of undesirable wood. Chip size distributions are made with the Williams Standard chip screen. Data from tests on effect of knife angle and knife settings on chip size are included. *From authors' summary.* [For. Prod. Util. Abs. V. 14, No. 1]

Avoid costly errors in buying plastic upholstery,
J. W. F. Young (The Federal Leather Co.)

Upholstering, U.S.A., Vol. 19 No. 10, October 1952, pp. 80–1, 170, 172, 6 illus.

Simple descriptions are given of the routine tests used by the Federal Leather Co. These tests serve two purposes: to determine what performance can be expected of the various grades of plastic upholstery produced by the company; and to ensure the maintenance of the standard quality.

Abrasion resistance is tested by rubbing a duck fabric against the surface of the plastic which must withstand 50,000 abrasions to be rated scuff-resistant. A flexing test determines the resistance to cracking and peeling, and a Fadeometer is used to find the resistance to fading and aging. Further tests are carried out on bursting strength, low temperature cracking and heat resistance. The plastic must show no tackiness after 60 min. exposure to temperature of 250° F., rising 10° every 10 min. to 300° F. The strength of the bond between the film and its supporting fabric is tested and an elongation test is used to determine strength. Various chemicals such as alcohol, solvents, etc., are rubbed into the plastic to determine its resistance to staining. [Tech. Bul. F.D.C., V. 3, No. 13]

Systematic quality control
B. C. Manson (California Redwood Association)

The Timberman, U.S.A., Vol. 53 No. 10, August 1952, pp. 76, 78–9, illus.

A simple introduction is given to the usefulness of quality control charts for reducing losses due to faulty manufacture. Some variations between products may result from chance causes inherent in the equipment and method of operation, but others may be due to definite outside causes, and these can be traced down and eliminated by means of control charts. Examples quoted are the use of charts for controlling the thickness of sawn boards within acceptable limits, and also moisture content. The plotting and interpretation of control charts for kiln dried timber are explained. These charts are arranged to show both the average moisture content of samples and the range of moisture contents encountered and can, in some cases, serve to indicate not only the presence of fault but also the source of trouble. Charts can also be used to show the percentage of defective boards with regard to such faults as chip marks and machine burns in surfacing. [Tech. Bul. F.D.C., V. 3, No. 13]

Pulp and Pulp Production

Hata, K., and Sogo, M. Studies on the pulp of Akamatsu (*Pinus densiflora* Sieb. et Zucc.). (XIV) The difficulties of sulphite pulping the heartwood. *Tech. Bull. Kagawa-Ken agric. Coll.* 3 (2), 1951 (111–8). 6 refs. [Jap.e.] A.P.B.

Temperature and chemical conditions at which pulping was most and least difficult were studied. [For. Prod. Util. Abs. V. 14, No. 1]

Tyden, H. Jjörk som råvara vid massaframställning. [Birch as raw material for pulp.] *Norsk Skogind.* 6 (6), 1952 (175–9). [Sw.e.] P.R

Discusses supply and costs in Sweden of Birch for pulping and tabulates figures showing the comparative yield and properties of Pine and Birch sulphate and Spruce and Birch sulphite pulp. [Cf. *For. Abstr.* 3 (Nos. 2596–7).] [For. Prod. Util. Abs. V. 14, No. 1]

Cohen, W. E., and Mackney, A. W. Influence of wood extractives on soda and sulphate pulping. *Proc. Aust. Pulp Pap. Ind. tech. Ass.* 5, 1951 (315–36). 9 refs. (Also as *Repr. For. Prod. Aust.* No. 160.)

Presents results of an investigation on the correlations between specified chemical properties of the woods of certain Eucalypts (hot-water solubles, and the consumption of NaOH in the sulphate pulping of *E. sieberiana, E. regnans,* and *E. obliqua,* and in the soda pulping of *E. obliqua, E. viminalis,* and *E. amygdalina*) and some pulp properties (lignin content, and $KMnO_4$ number). The correlations are represented by regression equations of the type $Y = ax + b$, and $Y = ax_1 + bx_2 + c$. The various correlations, together with their coefficients, are tabulated. [For. Prod. Util. Abs. V. 14, No. 1]

Wood Chemistry and Chemical Utilization

Swelling of wood. Alfred Nowak. Mitt. Osterr. Ges. Holzforschung No. 2, 25(1950).

The swelling of beechwood in air satd. with H_2O, alcs., acetone, ether, and halo hydrocarbon vapors was studied. For any single liquid, volumetric swelling (I) is proportional to amt. absorbed (up to a certain amt.). The above liquids give a family of swelling curves. If I is plotted against percentage absorption divided by d. of liquid, the data fall initially on the same curve. Beyond some absorption, at a fiber satn. point which is characteristic of each liquid, there is no further swelling. Since it is known that the pore vol. of wood does not change when wood swells, the above relationship implies that the pore vol. is unaltered when wood swells in the org. vapors. This is in contrast to heat swelling (e.g., thermal expansion) where the pore vol. does increase. Swelling is assocd. with the presence of polar groups in the swelling liquid. Swelling velocity

(of thin cross sections) in the liquids is inversely proportional to viscosity. Strength properties of wood decrease with increased swelling; however, for the same degree of swelling, strength reductions are greater with H_2O than with org. liquids. H. Tarkow [Chem. Abs. V. 46, No. 17]

Charles, E. La distillation moderne du bois. [Modern wood distillation.] *Chim. et Industr.* 67 (1), 1952 (56–62). 13 refs. [F.] D.S.I.R.

Describes different methods (predominantly French or used in France) applied before and after the war for the carbonization of wood with or without recovery of distillates. A detailed description is given of retorts with external and internal heating, and of the self-heating Stafford retort. The advantages and disadvantages of modern horizontal and vertical retorts are discussed. Various methods of treating the pyroligneous liquid are described. [For. Prod. Util. Abs. V. 14, No. 1]

The chemistry of the sulfite process. LI. Pinoresinol as a lignin model. Bengt O. Lindgren and Ulla Saeden (Roy. Inst. Technol., Stockholm). Acta Chem. Scand. 6, 91–5 (1952) (in English); cf. C. A. 45, 8762i.

Pinoresinol (1 g.) in 10 cc. soln. of Na_2SO_3 contg. 5% total SO_2 and adjusted to pH 7 with NaOH was heated 1.5 hrs. at 135°, Na ions were removed by passage through a cation exchanger, SO_2 expelled by a stream of N, the soln. neutralized with $Ba(OH)_2$, filtered, evapd. in vacuo, and the residue (1.47 g.) dissolved in H_2O. An equal vol. of iso-PrOH was added, the pptd. $Ba(SO_3)_2$ filtered off, and the product (1.05 g. sulfonated I) pptd. by the addn. of Me_2CO and Et_2O. The I dissolved at pH 2,4,6,8, and 10 was 18, 64, 97, 99, and 93%, resp. The dimethyl ether of I was similarly sulfonated; the quantity dissolved in 2 hrs. was 15 and 5% at pH 2 and 3, in 13 hrs. 15% at pH 3, and in 20 hrs. 8, 9, 8, and 0% at pH 4,5,6, and 11. John Lake Keays [Chem. Abs. V. 46, No. 16]

Triethylene glycol as a pulping agent and solvent for lignin. Bror L. Grondal and Piotri Zenczak. Trend 2–3. 24–5 (1950).

Wood chips were heated to 125° while immersed in 4 parts by wt. of triethylene glycol with and $AlCl_3$ catalyst. After H_2O is removed from the wood, the lignin complex dissolves rapidly causing defibration in 1 to 2 hours under atm. conditions. Under pressure, 1.5 to 2 parts solvent per 1 part wood is needed. After the cook, the solvent is recovered by draining and subsequent pressing. The recovered solvent is dild. with 1 to 1.5 parts water and the pptd. lignin is washed with water and dried at 80°. The resultant pulp showed promise of high strength and the lignin is compared with com. glues in the bonding of plywood samples. Thomas E. Kelley [Chem. Abs. V. 46, No. 16]

Solution of lignosulfonic acids from sulfite pulp with water at room temperature. Carl Kullgren (Roy. Inst. Technol., Stockholm). Svensk Papperstidn. 55, 1–12 (1952) (in German).

Unbleached sulfite pulp contains water-insol. lignosulfonates in varying amts. and K. has shown (C. A. 31. 4493°) that, after exchanging the cation with H ion, free lignosulfonic acid (I) dissolves by treatment with H_2O or alcs. The rate of soln. is slow at room temp., is unaffected by acidity of the soln., and is, at least at the start, inversely proportional to the amt. of I dissolved. By the hydrolytic soln., for each sulfonic group there appears a new free acid group—probably carboxylic. The latter group is not free in the solid I in the pulp; it there evidently serves to bind lignin to lignin. A week acid group, probably a phenolic OH, is present in solid as well as dissolved I in the ratio of 1 OH to 1 sulfonic group. The dissolved I is unstable, probably because of intermol. change; it darkens by boiling or with addn. of alkali. Some nitrates (e.g., Hg nitrate) ppt. the dissolved I. J. R. Salvesen [Chem Abs. V. 46, No. 16]

Miscellaneous

Forming dies made of densified wood. *Modern Metals,* Chicago 8 (1), 1952 (34). L.S.

Describes dies for deep and shallow drawing of aluminum parts, made of 'Hi-Den', a material built up of many thin wood veneers dried, impregnated with Bakelite liquid phenolic resin, dried in a heat cycle, and finally cured in a heat-and-pressure cycle that reduces the material to about ½ its original thickness. By varying the resin content and conditions of treatment, it is possible to obtain materials with tensile strength varying between 15,000 and 40,000 lb./sq. in., modulus of rupture between 20,000 and 46,000 lb./sq. in., and Izod impact from 3 to 8·5 ft. lb./in. 'Gaugewood' is a similar material made by another American company. [For. Prod. Util. Abs. V. 14, No. 1]

Latex foam in upholstery,

Furnishing, Vol. 65 No. 4, October 1952, pp. 287, 289–91, illus.

Useful hints are contained in this article on upholstering with foam rubber cushion units. Latex mouldings are usually supplied slightly over the nominal size quoted in order to give a slight compression in the finished job. Units should never be stretched when fitted. They can be supplied in varying degrees of hardness to suit the application. A back, for example, should be softer than a seat cushion. Means by which the upholsterer can modify the hardness of a moulding either locally or generally are suggested. Various types of base can be used provided the material is well supported and has access to air. With rigid ply or metal bases, holes should be bored in the base to correspond with cavities in the cushion. Stability is important and if possible the latex unit should be supported at the sides of the base for lateral stability. Any normal covering material may be used, but as leather tends to stretch when used over rubber units, it should be pleated to avoid unsightliness. Some cleaning agents are harmful to latex and the manufacturers' advice should be sought on this point.

General instructions on upholstering with latex, cover hand-building, shaping, joining, fitting tacking strip, and cutting. A bandsaw with a waved edge instead of teeth is useful for cutting mouldings and its use may be justified if the amount of cutting required is large. [Tech. Bul. F.D.C., V. 3, No. 13]

Anon. The Riegel Woodlands Corp. Pulp & Paper 26, no. 12:80, 82 (November, 1952).

The forest and land management for the Riegel Carolina 200-ton sulfate mill through its subsidiary, the Riegel Woodlands Corp., is described. The mill requires 450 cords of pulpwood per day; at the present time, only about 25% of this amount is produced from the Riegel Woodlands acreage. However, by careful cutting and reseeding practices, fire control, and acquirement of additional acreage, it is expected to obtain from 50 to 75% of the requirements from Riegel holdings. 3 illustrations. [Bul. Inst. Paper Chem. Vol. 23, No. 4]

Reid, J. S., and Wilson, M. E. Some properties of Loblolly Pine (Pinus taeda) grown in New Zealand. *For. Prod. Res. Notes N.Z. For. Serv.* 1 (2), 1951 (11–5 + 1 dgm., 5 tbls.).

Results of physical and mechanical strength tests on three trees are discussed and tabulated. Variations in properties with height in tree are shown diagrammatically for one tree. [For. Prod. Util. Abs., V. 13, No. 5]

Rambo, W. H., and DeRice, H. A. Economics of log debarking in sawmills. *Lumberm.* 79(5), 1952 (94, 96, 132).

Gives estimated costs of sorting, ripsawing, slab and whole-log barking, and chipping, together with estimated chip recovery. [For. Prod. Util. Abs., V. 13, No. 5]

Incisor solves Cedar bark problem. *Timberman* 53 (6), 1952 (60).

Describes, with illustrations, an incising machine which, by cutting the bark on the log into 12-in. sections, reduces its stringy characteristics and eliminates the clogging of conveyors during the barking process. [For. Prod. Util. Abs., V. 13, No. 5]

The lumber must be flat and of uniform thickness; the edges must be straight and square, and it should be surfaced just before gluing. The curing cycle should be balanced against the make-up time. The peak voltage values vary from 800–1200 volts for Cherry and Mahogany to 1500–2500 volts for Beech, Birch, and Maple.

Report of the Fire Research Board for 1951

H. M. Stationery Office, London, 1952, 44 pp. 2*s*

This report deals with the work of the Fire Research Board and covers a wide range of subjects. It may be of interest to the furniture industry in connection with fire risks in factories and also the effect of domestic furniture on fires in homes.

A point of special interest is that a small scale test for determining the surface spread of flame has been devised. This is useful where more frequent tests are required than are normally possible using the large scale method described in BS 476. In view of the importance which is now attached to the spread of flame as opposed to combustibility, this development will be welcome to firms concerned with fire resistant materials.

Among the fundamental studies carried out has been one dealing with the effect of radiant heat on timber and textiles. It has been found that actual contact between the surface of timber and a small flame has an appreciable effect on the radiation required to cause ignition. A comparison has been made of the ignition properties of wool, cotton and linen and a formula is given showing the effect on such material of radiation. A study has been made of the combustion of polyvinyl chloride plastics which, it was thought, might give off poisonous gases in the event of a fire. The tests that have been made show that the products of combustion are not more dangerous than those of normal fires. [Tech. Bul. F.D.C., V. 3, No. 13]

Species sampling on a reproducible basis. C. M. Stewart, D. H. Foster, W. E. Cohen, R. T. Leslie, and A. J. Watson (Commonwealth Sci. Ind. Research Organization, Melbourne, Australia). Proc. Australian Pulp Paper Ind. Tech, Assoc. 5, 267–311(1951); Tappi 35, 129–33 (1952).

A large no. (20 +) of samples taken from the 12 outer heartwood growth rings of Eucalyptus regnans were analyzed chemically, and the coeffs. of variation of the different analyses calcd. From these coeffs., it is shown how to calc. the no. of trees necessary to sample in order that the results of the analysis of a composited sample be within specified limits away from the "true av. analysis," F T. Ratliff [Chem. Abs. V. 46, No. 16]

Snow, E. A. Oak Slabs and cordwood as a source of tannin and pulp. J. Am. Leather Chemists Assoc. 47, no. 8: 563–77 (August, 1952); *cf.* **B.I.P.C. 20: 208.**

Laboratory and commercial-scale studies initiated by TVA in 1944–45 showed that heavy leather of good quality can be produced with tannin extracted from oak sawmill waste, but that the cost per tan unit was slightly higher than when chestnut wood was used. A pilot-plant study was undertaken at Norris, Tenn. to discover whether separating bark and wood from chipped-oak waste prior to extraction would reduce the cost differential. The advantages of wood-bark separation would be the production of wood suitable for pulping and the extraction of a tannin from the bark at half the cost. The process includes chipping and screening operations followed by separation on a specific-gravity type, air-float separator. Tests of different styles of chippers indicated the V-cylinder, open-style throat, sawmill hog to be most satisfactory for separations by this process. [Bul. Inst. Paper Chem., V. 23, p. 129]

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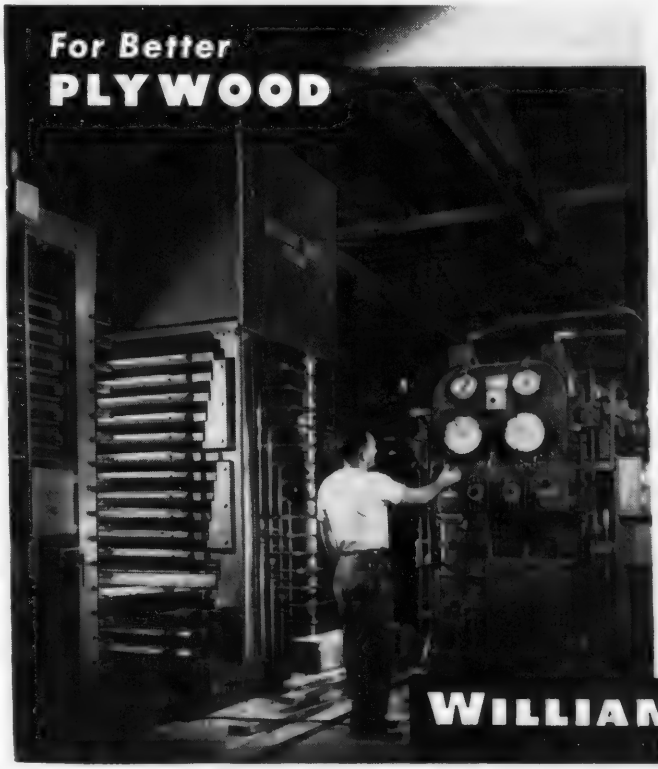

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Vaughn Millwork Co., Reno

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Oval Wood Dish Corp., Tupper Lake
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United States Plywood Corp., New York
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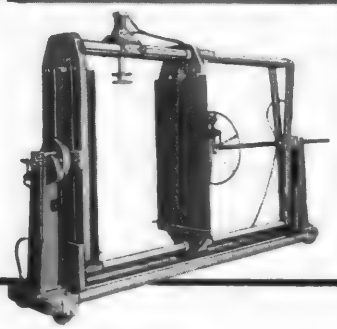

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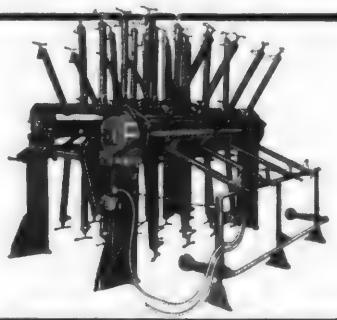

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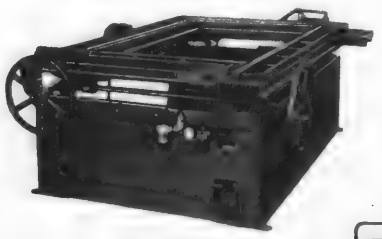

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FPRS NEWS-DIGEST

FOREST PRODUCTS RESEARCH SOCIETY, P. O. BOX 2010, UNIVERSITY STATION, MADISON, WISCONSIN

Volume 3 JUNE, 1953 Number 6

This Month's Cover—On June 15–17, at Memphis, Tenn., guidance of the FPRS will be passed on from one forward looking man—Kenneth G. Chesley—to another—Robert D. Pauley. It is indicative of the Society's growing strength and influence that its leadership is in the hands of men whose every-day work is concerned with research, development, production, utilization, and distribution. The membership can confidently look forward to the same steady progress in 1953–54 that has been made during the past year.

Retiring president Ken G. Chesley is Director of Research for the Crossett Lumber Co., Crossett, Ark., an organization famed for its modern forestry, manufacturing and distribution policies, and for the high utilization of raw material it achieves through integrated operations ranging from lumber to pulp and paper.

Drawing on this broad experience, Chesley has given untiringly of time and knowledge to help FPRS increase in service and value to the Industry. Charter member number 2 completing his seventh consecutive year as a Society officer, president Chesley has encouraged the addition of working subject matter committees in many fields, and establishment of a technical Journal for the industry, with a full-time editorial staff. Two new Sections, the Ohio Valley and the Eastern Canadian, have been added, increasing the total number of Sections to 13. Finally, Chesley has traveled extensively throughout the county on Society business during his tenor of office.

President-elect Robert D. Pauley, Manager of the Special Products Division of the Weyerhaeuser Timber Co., Tacoma, Wash., also brings experience and knowledge in the fields of

(Continued on page 105)

TIME TABLE OF EVENTS AT MEMPHIS

Sunday, June 14

9:00 A.M. FPRS Executive Board
8:00 P.M. Education Committee Meeting
8:00 P.M. National Advisory Committee

Monday, June 15

7.45 A.M. Authors' Breakfast
8:30 A.M. Registration
9:00 A.M. Glues and Gluing Committee Meeting
9:00 A.M. Wood Drying Committee Meeting
10:00 A.M. Quality Control Committee Meeting
Packaging Committee Meeting
Wood Machining Committee Meeting
Wood Finishing Committee Meeting
11:00 A.M. 7th Annual Business Meeting
12:00 P.M. Luncheon Meeting—National Advisory Committee and Executive Board
2:00 P.M. Sessions I & II
7:00 P.M. to 10:00 P.M. 50 exhibits of literature, Educational displays on mezzanine floor
7:30 P.M. Wood Composition Board Committee Meeting

Tuesday, June 16

7:45 A.M. Authors' Breakfast
8:30 A.M. Registration
9:00 A.M. Sessions III and IV
12:00 P.M. FPRS Annual Luncheon
2:00 P.M. Sessions V and VI
6:00 P.M. "Paul Bunyan Hour"—sponsored by over 40 suppliers to forest products entries
7:30 P.M. FPRS "Party"—dinner and floor show

Wednesday, June 17

7:45 A.M. Authors' Breakfast
8:30 A.M. Registration
9:00 A.M. Session VII
9:00 A.M. Plant Tours to E. L. Bruce Co., Nickey Bros., Hungerford Furn.
2:00 P.M. Session VIII
2:00 P.M. Plant Tours to E. L. Bruce Co., Nickey Bros., Hungerford Furn.
3:00 P.M. Meeting of New Executive Board

For the Ladies

A full schedule of events for the ladies coming to Memphis has been planned in conjunction with the National Meeting.

Monday is an open day and will be devoted to visiting the wide array of fine stores and the scenic points immediately adjacent to the downtown area, including parks overlooking the Mississippi.

Tuesday the ladies are invited to attend the official FPRS luncheon, the Paul Bunyan cocktail hour, and the official FPRS party, which includes dinner, entertainment and dancing. Luncheon and dinner tickets will be available.

Wednesday is "Ladies' Day" and will feature an extensive auto tour to zoos, museums, parks, educational institutions, famous homes, and other scenic points. A special ladies' luncheon is planned either at the University club or one of Memphis famous country clubs. The entire day is included in the Ladies' Registration.

"Paul Bunyan Hour" Sponsors Listed

Over 40 companies have contributed toward the traditional "Paul Bunyan Hour" and entertainment for the evening of June 16. Refreshments will be served from 6:00 P. M. to a time

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Meet the Men Who Are Running the Memphis Meeting

Moss B. Christian, left, is general meeting chairman. W. Jeter Eason, right, is National Meeting Chairman. Chairmen of Eason's local committee include James R. Massey, publicity; Henry H. Willins, General Arrangements; Dan Copp and Richard Wilson, Finance. Assistants include James Wiseman and L. J. Heatherly.

SESSION I
Charles Latimer

SESSION II
Alan A. Marra

SESSION III
Reavis Sproull, Technical Director, Hearty Foundation

SESSION IV
Earl Stivers

SESSION CHAIRMEN

SESSION V
B. E. Clatworthy

SESSION VI
George G. Marra

SESSION VII
L. A. Patronsky

SESSION VIII
Roy M. Carter, General Chairman, Subject Matter Committees

prior to the FPRS dinner and floor show following the "Paul Bunyan Hour." The names of the sponsors will appear on special cocktail napkins and sponsors will be identified by special badges. Sponsors to date include:

Yates-American Machine Company, Beloit, Wis.; Pacific Lumber Company, Scotia, Calif.; Rohm & Haas, Philadelphia, Pa.; National Casein Company, Chicago, Ill.; Perkins Glue Company, Lansdale, Pa.; Woodworking Digest, Inc., Wheaton, Ill.; American Manufacturing Company, Tacoma, Wash.; The Borden Company, New York, N. Y.; Rockwell Manufacturing Company, Washington, D. C.; Onsrud Machine Works, Chicago, Ill.; The Carborundum Company, Niagara Falls, N. Y.; Kirk & Blum Manufacturing Company, Cincinnati, O.; Protection Products Company, Kalamazoo, Mich.; Gleworth Publishing Company, Greenwich, Conn.; Jenkins Machine Division, Sheboygan Falls, Wis.; Masonite Corporation, Chicago, Ill.; Ekstrom, Carlson & Company, Rockford, Ill.; Drake Company, St. Louis, Missouri; Fjellman & Winther Engineering Company, Joliet, Ill.; American Cyanamid Company, New York, N. Y.; Reichhold Chemicals, Inc., New York, N. Y.; Chapman Chemical Co., Memphis, Tenn.; Southern Lumberman, Nashville, Tenn.; Bell Machine Co., Oshkosh, Wis.; Woodwelding, Inc., Burbank, Calif.; C & D Welding Service, Reading, Calif.; Siempelkamp, Krefeld, Germany; Plycor Co., Chicago, Ill.; Merritt-Solem Corp., Lockport, N. Y.; Simonds Saw & Steel Co., Fitchburg, Mass.; Snyder Chemical Co., Bethel, Conn.; Coe Mfg. Co., Painesville, O.; The Wheland Co., Chattanooga, Tenn.; S. H. Smith Co., Indianapolis, Ind.; Moisture Register Co., Alhambra, Calif.; Moore Dry Kiln Co., Jacksonville, Fla.; Henry Disston & Sons, Philadelphia, Pa.; Mann-Russell Electronics, Tacoma, Wash.; Clark Equipment Co., Battle Creek, Mich.; Redco Tool Division, Red Lion, Pa.

Heavy Demand for Table-Top Exhibit Space

The literature and educational exhibit, featured at earlier National Meetings of the Society in 1947 and 1948, will be renewed this year at Memphis. Every available exhibit space, of which there will be some fifty, was reserved almost a month ago. Two principal types of exhibits—those containing samples of product and other literature and visual, educational exhibits—will be designed to acquaint visitors with the latest in new equipment, products, processes, education and laboratories. The exhibits will occupy the mezzanine floor where the technical sessions will be conducted. The exhibit will continue from Monday morning, June 15, through June 17. The big feature will be "Suppliers' Night" from approximately 6:00 p. m. to "?" Monday night, June 15.

In addition to many "Paul Bunyan Hour" sponsors, the following institutions will be represented:

Canadian Forest Products Laboratory
North Carolina State College
University of Michigan
Michigan State College
State University of New York
U. S. Forest Products Laboratory

Subject Matter Committee Meetings Are Added Attraction at 1953 Meeting

All established committees and several new ones, organized to strengthen and coordinate FPRS National and Sectional activities with respect to specific fields of wood industry activity, will hold meeting at Memphis. The majority of these meetings will be open for all interested persons to attend.

PACKAGING—First open meeting of this group to formulate general plans for future activity.

WOOD DRYING—A closed committee meeting.

QUALITY CONTROL—An open meeting to review proposed Manual of Terminology and establish future work program.

COMPOSITION BOARD—An open meeting which will include a report on the European composition board field; summary of hardboard developments in the Northwest; and summary of the activities of the Hardboard Division of the FPRS Pacific Northwest Section.

GLUE—An open meeting to discuss future program, current research, and presentation of five reports ranging

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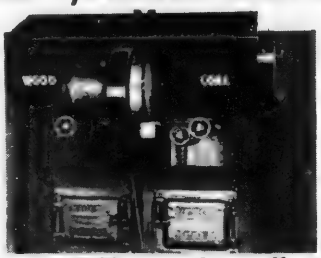

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from glueability of veneer, gap filling properties, edge glued joints, evaluating test methods, to durability testing.

MACHINING — Development of standard nomenclature of woodworking tools and cutters toward the establishment of a usable manual for the industry.

FINISHING—Semi-closed meeting expected to advance work from progress made at previous National Meeting.

THE CARBIDE STANDARDIZATION Committee of ASME expects to hold a meeting at Memphis, time and place to be announced later.

PAULEY

(Continued from page 101)

integration and utilization to the office of Society President.

For a number of years after graduation from Iowa State College, Pauley was associated with Weyerhaeuser interests at Cloquet, Minn. Subsequently, he was transferred to Longview, Wash., where he supervised the construction of the Weyerhaeuser Development Center, and had a prominent part in many notable technical advancements in the integration of new processes and the merchandising of Weyerhaeuser products. These include exterior plywood, compression barking, the "Silvacon" bark products for adhesives, oil well drilling additives, molding compounds and many other industrial uses, the Silvacel whole wood fiber products, for thermal insulation, industrial felts and papers, and molded contoured articles, fiber boards of wide variety and a new laminated veneer sheet material for containers of many designs.

Today Pauley directs both manufacture and sales of the Special Products Division of the Weyerhaeuser Timber Company. One of his most significant current activities is the Klamath Falls hardboard plant, which is expected to be in full-scale operation later in the year.

Pauley is a charter member of FPRS, having joined in 1947. He has been one of its most active members, literally "growing up" through the ranks of committee work and chapter affairs to the Presidency.

He served as Northwest Regional Board Member from 1948–1951. He also has served as chairman of the Executive Board sub-committee on regional and sectional boundaries; as general chairman of the Society's 1950 National Meeting and Industry Show held in Portland, Ore.; as National Chairman of the membership and finance committees; and as Vice-President; and President-Elect.

INDUSTRY NEWS

Canadian Editor Makes Plea for Research

Jack Wright, Editor of Canada Lumberman, in an editorial in the April issue of that publication, presents a strong case for the work being accomplished by FPRS. After painting a picture of the inroads of competing products in wood's markets, Wright calls the recent formation of the Eastern Canadian Section a "bright spot" and looks to the time Canadian interest and membership in the Society will warrant a Canadian Region. "Achievement of this goal," says Wright, "will indicate that Canadians have 'arrived' in forest products research."

Testing Adhesives

The ASTM has recently published a "Symposium on Testing Adhesives for Durability and Permanence." The publication contains five papers relating to various phases of adhesive permanence. The volume is available from the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Price to members is $1.35; to nonmembers $1.75.

Forestry Handbook Available

The Research Committee of the Forestry Undergraduate Society published a Technical Forestry Handbook for British Columbia on May 31st, 1953. It contains a compilation of useful information for foresters, engineers, and lumbermen. The project was organized three years ago to fill the need for a forestry handbook. The Research Committee has previously published a series of Seven Research Notes during the past three years.

This Handbook comprehensively covers the most important phases of forestry in B. C. It will be a volume of approximately 350 pages and will be of pocket size. (5½ x 7½".)

There are twelve chapters in the Handbook and the titles are: Engineering, Sampling Techniques, Forest Protection, Forest Entomology, Forest Pathology, Tree Identification, Forest Classification, Silviculture, Forest Management, Wood Identification, Ownership and Disposal of Crown Land, and Volume Tables. Some of the text is illustrated, for example, the chapters on Entomology and Pathology.

The Handbook is available from the Forestry Undergraduate Society, Forestry and Geology Bldg., U. B. C., Vancouver 8, B. C. Price is $3.00 (Canadian) plus 3% sales tax.

Forestry Film Traces Utilization Growth

Western Pine Association, 510 Yeon Bldg., Portland, Ore., has released a new color, sound film which documents the growth, harvest, manufacture and utilization of lumber produced in the western pine area. Copies are available for showing to responsible persons and groups. Only charge is for shipping costs. Black and white prints are available for television. Requests for bookings are invited through Western Pine Association.

Industry Course Scheduled at Michigan for August

Practical problems of the wood working industry will be covered in an intensive one-week course at the University of Michigan Wood Technology Laboratory August 10–15. The course is designed for executives, plant personnel and quality control men. Fred E. Dickinson, Chairman of the Department of Wood Technology, will be course director. Applications should be made in writing to Institutes Department, U. of Michigan, Ann.

Accounting Manual Finds Ready Reception

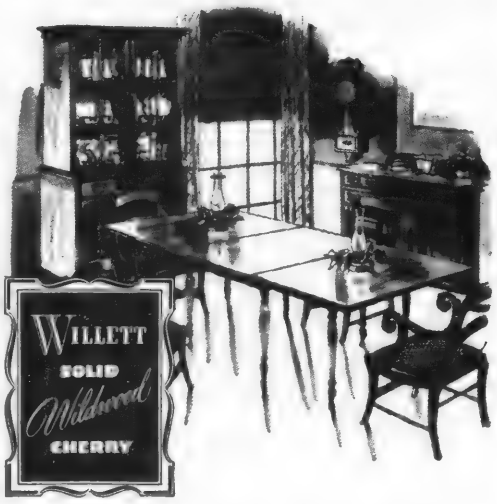
"Accounting and Cost Controls in the Hardwood Conversion Industry" (see January News-Digest) has enjoyed a wide distribution to date, including many requests from foreign countries. The manual was authored by Vincent E. Noltemeyer, Secretary-Treasurer of Gamble Bros., Louisville, Ky., for the Hardwood Dimension Manufacturers Association's Cost Accounting Committee. The volume stresses the importance of proper accounting and cost control in woodworking plants, and gives explanatory examples of suggested methods. Available through Vincent E. Noltemeyer, 4601 Almond Ave., Louisville, Ky. Price, $6.00.

SECTION NEWS

N. Calif. Sections Takes Part in Radio–Telephone Forum with Philippines

With representatives of the Philippine Republic looking on, the first simultaneous demonstration of direct radio telephone and telegraph communications with the Philippines ever staged before a group meeting in the bay area, took place Wednesday, May 6.

The event was part of the dinner program of the Northern California Section meeting at the Palace Hotel. The demonstration was arranged by Harry E. Austin, vice president in



FRANK M. BRANDON, Vice President of

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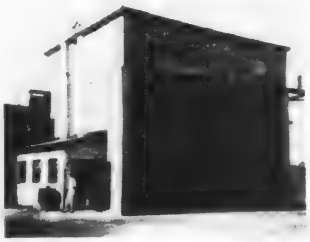

This is the *Standard* kiln referred to by Mr. Brandon. One of the biggest single package kilns, it is 34 ft. wide, 26 ft. deep, and has a door opening 22 ft. high with no pilasters.

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charge of Pacific Coast Activities of RCA Communications. Austin was also the main speaker of the evening.

Special guests from the Philippine Consulate General were Mr. Jose Q. Tabora, Vice Consul in charge of the Commercial Division and Mr. Guillermo Fonacier, Administrative Officer of the Consulate. At RCA's Manila office were Florencio Tamesis, Director of Forestry for the Philippine Republic, who discussed, by radio and simultaneously by telegraph, forest management problems with L. J. Carr, first vice-president of FPRS, who spoke from the Palace's California room. The conversation was opened by Mr. Jose Q. Tabora, who introduced Carr to the Philippine official standing by in Manila.

Later, in his speech to the California group, Austin traced the development over the past two decades of electronic communication and the contributions it has made to commerce and industry.

F–G–A Selects New Officers

At an Executive meeting April 6, at Valdosta, Ga., Reavis C. Sproull, Technical Director, Herty Foundation, Savannah, Ga., was picked to succeed Milton Ryberg, who resigned from the post upon leaving the section area. Dean Boyd Richards, Alabama Polytechnic Institute, Auburn, became vice-chairman, a post formerly held by Sproull. J. F. McGowin, W. T. Smith Lumber Co., Chapman, Alabama, was appointed Trustee to fill Richard's place.

Plans were made to hold a fall meeting at Radium Springs hotel, Albany, Ga.

Ohio Valley Section Hears Papers, Tours Plant

FPRS members and guests attended the April 23–24 meeting of the Ohio Valley Section at New Albany, Ind., and Louisville, Ky. The afternoon of the first day was spent in plant tours to the Chester B. Stem plant, Gunnison Homes, Breece Veneer and Panel Co., and Anderson Woodworking Co. Technical sessions were held at the Stem plant the morning of the first day and at the University of Louisville the second day. Sessions were under the chairmanship of Robert E. Allen, National Casein Co.

Northeast Meet at Portland, Maine, Attracts 151

One hundred and fifty FPRS members, members of the Western Maine Forestry Forum, and guests attended the May 7–8 meeting of the Northeast Section at Portland, Me. Theme was "Improved methods for more haste with less waste." Sixteen prominent authorities discussed "efficient log and lumber handling and processing and utilization."

Plant trips were made to the Gunter Lumber Co.'s mill to view utilization practices, and to the Sloane Blabon wood flour mill.

Wood Drying Committee Reports Drying Problems

Chairman Ray Rietz of the FPRS Wood Drying Subject Matter Committee reports on the April meeting of the New England Kiln Drying Association. Arthur Koehler (Yale School of Forestry) is quoted at length on reasons for cupping, bowing, crooking, diamonding and collapse. Copies of the report are available from Ray Rietz, care of the Forest Products Laboratory, Madison 5, Wis.

Midwest Section Schedules Summer Meeting at Madison

The Midwest Section will hold a two-day business-social meeting July 23–25 at Madison, Wis. On the afternoon of July 23 various members of the U. S. Forest Products Laboratory will present a program at the Laboratory. A forum by industry men will be presented at a downtown hotel on the morning of July 24. Friday afternoon will be open for group social activities.

H. O. Fleischer of the Laboratory is general arrangements chairman and Wayne C. Lewis of the Laboratory is in charge of publicity. Harold J. Fasbender, Harnischfeger Corp. Port Washington, Wis., is in charge of the industry program.

Boston "Extension" Meeting Discusses Laminating

Fifty structural engineers, architects, Naval architects, ship builders and contractors from the Boston area kept the March District Extension Meeting of the Northeast Section going at a hot pace. The panel and the audience thoroughly investigated the many facets of structural laminating. Panel moderator was A. G. H. Dietz, Prof., Structural Engineering, Mass. Institute of Technology.

Northeast Section Student Award Winners

Prof. Eric A. Anderson, New York State College of Forestry, Syracuse, Chairman of the Northeast Section Committee on Annual Award for the Outstanding Forest Products Senior, has announced two 1953 winners.

First place award of $100 went to Robert W. Kennedy, Wood Technology major, College of Forestry State University of New York, Syracuse. Second place award of a one year FPRS student membership was won by Carl. D. Perkins, Pulp and Paper major, Dept. of Chemical Engineering, University of Maine, Orono.

Kennedy and Perkins were invited to the May 7–8 Northeast Section Meeting at Portland, Me., to receive their Awards.

IMPORTANT FPRS DATES

July 23, 24, 1953: Midwest Section Meeting at Madison, Wis.

Sept., 1953: Upper Mississippi Valley Meeting at Duluth, Minn.

Oct.–Nov., 1953: Florida–Georgia–Alabama Meeting at Radium Springs, Ga.

Nov. 5, 6, 1953: Northeast Section Meeting at Yale U., New Haven, Conn.

Northern California Section Elects Officers

At the May 6 meeting of the Northern California Section at San Francisco the following officers were elected: Chairman, Lee Moffett, Tarter, Webster and Johnson, Inc., Stockton; Secretary-Treasurer, Homer Stevens, Sacromento Box and Lumber Co., Sacromento; and Vice-Chairman, James C. Rowney, Rowney Machine Works, Oakland; Trustee: Arthur O. Horner, Timber Structures Co. of Calif.

Furniture Subject Matter Committee for Northeast

Northeast Section Chairman Frank T. Parrish, Gardner, Mass., reports formation of a Subject Matter Committee on Furniture for that Section. Members of the committee include Joe Adkinson, Home Furniture Co., York, Paa.; Jim Sechrist, Red Lion Cabinet Co., Red Lion, Pa.; Carlton Nichols, Nichols and Stone Co., Gardner, Mass.; Dave Schoonmaker, W. F. Whitney Co., S. Ashburnham, Mass.; Tim Creal Paramount Furniture Co., Warren, Pa.; and Jim Tillotson, Tillotson Furniture Co., Jamestown, N. Y.

Warner Appointed Deep South Trustee

The Executive Board of the Deep South Section has appointed W. R. Warner, Manager, Southern Lumber Co., Warren, Ark., as Trustee to fill the unexpired term of Jack Hammond. Southern Lumber Co. is an FPRS Supporting Member.

New Publications

Review of Current Research and Directory of Member Institutions (1951). Available from the Engineering College Research Council of the American Society for Engineering Education at the Georgia Institute of Technology, Atlanta, Georgia. Contains review of all types of research facilities at U. S. universities. Omits almost entirely wood research at forestry schools and other institutions not directly connected with engineering schools.

Semi-Annual Report, Forest Products Laboratory Division, Ottawa Laboratory–Vancouver Laboratory. Reviews status of various research projects in progress, and lists publications, papers and personnel activities. Limited circulation. Information on work of laboratories may be obtained by writing either Ottawa or Vancouver.

Household Furniture and Bedding Reports—1949–50–51. Available Bureau of Census, Washington, D. C. No. 151.41 H 81. Contains detailed statistics on productions of wood, upholstered and metal furniture by groups, for regions and states. Also shows number of manufacturing plants and value of shipments by size plant and by major product shipped.

Proof Book of Forestry Ad Mats —1953 edition. Contains proofs of American Forest Products Industries, Inc. prepared ads to promote better forestry, as well as better public understanding of forestry. Available from American Forest Products Industries, Inc., 1816 N Street, N. W., Washington 6, D. C.

More Wood Per Tree by Careful Felling and Bucking. George Stenzel. Single copies available free from the Institute of Forest Products, 303 Anderson Hall, Univ. of Washington, Seattle 5, Washington. Requests for more than one copy will cost 10 cents each to cover cost of printing. Relates proper procedures to follow to gain maximum log value from the tree. Tells proper undercuts, stump heights, as well as how to gain maximum grade value through correct bucking. Also lists steps in proper care of chain saws and other tools.

Good Logging Practices Increase Forest Yields. J. A. Doyle. Available from Canadian Forest Products Laboratory, Ottawa, Ontario (reprinted from Timber of Canada, Feb. 1953). Reviews increase in economic value of forests that can be realized from good logging practices. Points out research in logging operations has lagged and is now immediately needed. Also utilization of residue and low grade products must be continually improved to make more complete harvesting economically feasible.

Housing Research No. 5. Housing and Home Finance Agency. Available: Supt. of Documents, U. S. Government Printing Office, Washington 25, D. C. (Price 40 cents). Contains among others articles on trussed roof construction, showing savings achieved on demonstration house as compared to control house and article on exterior house paints, showing basically different types of formulations.

End Joints for Southern Pine. D. B. Richards and B. M. Cool. Leaflet No. 39. Available from the Agricultural Experiment Station of the Alabama Polytechnic Institute, Auburn, Alabama. Describes new end joint to develop maximum strength in 1 inch and 2 inch Southern Pine. Points to utilization of shorts to develop sizes more in demand. Tests show minimum number of truncated tips and scarf angles of between 1:4 and 1:8 are best. Truncated tips near surface of board and broad tips should be avoided.

Laboratory Notes—January 1953. Describes panel tests to help in design of wood buildings—especially tests on three full-scale roof panels. "Cushion" effect wood found in tests indicates value of wood construction in earthquake areas. Available from Oregon Forest Products Laboratory, Corvallis, Oregon.

Brown Stain and Its Effect on the Strength of Pine Poles. Clara W. Fritz. Available from Canadian Forest Products Laboratory (reprinted from Forestry Chronicle, Sept. 1952). Relates tests to determine fungus that causes brown stain, and describes method devised obtaining satisfactory staining of samples for test purposes. Very little difference in strength was found between stained samples and control samples. There was, however, significant lowering of specific gravity.

The Use of Sawdust for Mulches and Soil Improvement. Circular No. 191—U. S. Department of Agriculture, Washington, D. C. Available from U. S. Dept. of Agriculture, Washington, D. C. Reviews in some detail benefits and techniques, as well as problems, in using sawdust as a mulch, and in place of manure as conditional. Such usages are promising outlet for excess sawdust.

The Hot-and-Cold Bath Preservative Treatment of Jack Pine and Spruce Crossarms With Pentachlorophenol Solution. J. Krzyzewski. Mimeo Report No. 0–166. Available from Forest Products Laboratory, Ottawa, Ontario, Canada. Describes various penta treatments of Jack Pine and Spruce Crossarms, listing results in terms of retention. In case of Jack Pine, net retention of 7 lbs. per cubic foot of 5 percent solution would appear satisfactory to give good service. Spruce showed poor absorption and this type treatment is not suggested.

The Preservative Treatment of Fenceposts by Non-Pressure Processes. M. J. Colleary. Bulletin No. 107. Available from Department of Resources and Development, Ottawa, Ontario, Canada. Gives practical explanations on how to use various non-pressure methods for treating fence posts, and lists probable results in terms of extended life that may be expected in various species, based on type of treatment and kind of preservative material used.

Vacuum Sealer Units. Bulletin No. 1980, available from Wood Treating Chemicals Co., St. Louis 10, Mo. Describes vacuum sealer units, operation, specifications and applications, as well as tests to determine retention of preservative with vacuum treatment as compared to dip method. Describes and illustrates installation of typical plant.

Vacuum Treating Plant—Economic Study and Data Brochure. Available from Chapman Chemical Co., Memphis, Tenn. Describes vacuum treating process, and details various steps entailed in constructing and equipping a plant for using this process. Also gives typical schedules, specifications, as well as operating costs, profits possible, and probable return on investment.

List of Publications. Available from Forest Products Laboratories, Dept. of Resources and Development, Ottawa, Ontario and Vancouver, B. C. Canada. List of publications and reports of the Forest Products Laboratory Division—including Forest Products Laboratory, Ottawa and Forest Products Laboratory, Vancouver. Includes bulletins, circulars, mimeographs and reprints of articles and papers which are available for distribution.

Do you know all potentialities of wood residues?

CHEMICAL PROCESSING OF WOOD

By ALFRED J. STAMM, Ph. D.
Chief, Division of Derived Products

and ELWIN E. HARRIS, Ph. D.
Subject Matter Specialist in Wood Hydrolysis and Lignin Chemistry
Forest Products Laboratory, U. S. Department of Agriculture,
Madison, Wisconsin

contains all the answers.

A unique compilation of scattered data

This book was written with the object of assembling all available information on the chemical utilization of wood, especially of wood residues and inferior species of wood, by both conventional and new methods, to produce modified wood products, pulp products and various derived chemicals.

The chief emphasis is placed on the more recently developed processes which have not been previously included in books. To make this material readily understandable and usable, introductory chapters have been devoted to the fundamental physical and chemical properties of wood.

CONTENTS

CHAPTER

1. Wood as a Chemical Raw Material.
2. The Constituents of Wood.
3. Structure of Wood.
4. Surface Properties of Wood.
5. Mechanical and Thermal Properties of Wood and Wood Products.
6. Drying Wood.
7. Preservative and Fire-retardant Treatments of Wood.
8. Modified Woods.
9. Wood-base Plastics.
10. Pulp and Paper.
11. Pulp Boards and Paper-base Laminates.
12. Cellulose Derivatives.
13. Tree Exudates.
14. Destructive Distillation of Wood.
15. Extractives.
16. Wood Hydrolysis.
17. Hydrogenation of Wood and Wood Products.
18. Miscellaneous Products from Wood.

New techniques

The manufacture of Impreg and Compreg, the preparation of Staypak and acetylated wood, new techniques for molding these and other products, wood-base plastics, high-strength paper laminates, lignin-filled laminates, pulp preforms, low-density core materials, chemical seasoning and solvent seasoning methods, hydrogenation of lignin and wood, wood-sugar molasses, fermentation products, growing yeast and wood sugars, and vanillin production from wood are among the many interesting topics covered in this comprehensive volume.

A critical review of all wood modifying processes

The book is not a mere compilation of literature data, but a critical survey which presents both the favorable and unfavorable features of each process, together with the economic limitations.

Although it was written primarily for the chemist and engineer, the simple and straightforward style will make this book profitable reading to businessmen and executives who are interested in the utilization of our natural resources. It is also suitable as a text, especially for forestry schools.

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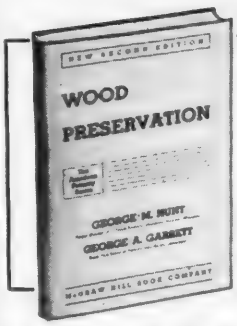

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WOOD PRESERVATION

Second Edition

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Here is a completely up-to-date guide book for all interested in the materials and methods of prolonging the life of wood or improving its usefulness by treatment with chemicals or by sanitary precautions.

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Volume I

Structure, Identification, Defects, and Uses of the Commercial Woods of the United States

This volume meets your most exacting needs for practical information on wood anatomy . . . distinguishing features of various wood species . . . keys for the identification of woods by gross and minute characters . . . etc. It covers in detail topics ranging from plant origin of wood to cambia of trees; from wood anatomy of Northern white pine to minute structure of porous woods; from figures in wood to natural durability of wood with respect to foreign organisms. Here is precise reference data on more than 7 domestic woods. **628 pages, 322 illus., $7.50 to FPRS members $6.75**

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Dry rot and other timber troubles, by W. P. K. Findlay. 267 pp., 58 figs. Hutchinson's Scientific and Technical Publications, London. 1953. Price 25 shillings.

Is well organized and should be understandable to a wide audience but at the same time be appealing to the technical products pathologist. The latter will miss literature references, which are few and mainly of a general nature.

The book comprises 12 chapters. The first two describe the structure, chemistry, and durability of wood and the physical, chemical, and biological decomposition of wood. In the succeeding four chapters, fungus decay, stains, insect attack, and diseases of standing trees in so far as influencing products made from them are considered. Stress throughout is on adequate diagnosis of troubles as the first need for control. These clearly and simply written sections are good reviews to bring the technical reader up to date or to ground the general reader in the fundamentals. Only two important shortcomings were noted. First, the author is more lenient on stain and mold as defects in wood than we are in recent literature. The much greater permeability, particularly of molded wood, deserves attention in relation to many wood use problems. Secondly, nitrogeneous materials, added to wood, do not always increase decay rate. Noteworthy practical exceptions not mentioned are certain nitrogenous fire retardants and chemical seasoning agents that impart appreciable decay resistance. In general, though, the sections on physiology of decay fungi and the effects of decay on wood are particularly good.

The remaining chapters deal with more practical problems: prevention of deterioration in felled timber, preservatives, and prevention of decay in buildings, garden wooden articles, boats, vehicles, aircraft, and miscellaneous products. The American reader will find much useful information in these chapters but must remember the book is written for English conditions, which are not always identical with ours.

Semi-Permanent Band Mill Operation. David P. Thomas. Available from Institute of Forest Products, 303 Anderson Hall, Univ. of Washington, Seattle, Washington (Circular No. 25). Describes semi-permanent band mill operating under normal conditions, and relates study of production. 46 percent lumber overrun was obtained cutting second-growth-farm wood lot logs averaging 12 inches in diameter and 16 feet in length.

A Preliminary Investigation of Veneer Cutting Properties of Aspen Poplar. D. G. Miller. Mimeograph O–167. Available from Canadian Forest Products Laboratory, Ottawa, Ontario, Canada. Describes preliminary investigation of study to determine optimum technique for converting aspen poplar into plywood. Present tests determined optimum lath settings for cutting veneer. On basis of comparatively small sample it appears aspen poplar can be converted into a good grade of plywood suitable for a variety of uses.

The following publications are available from the U. S. Forest Products Laboratory, Madison 5, Wis.

Methods of Determining the Specific Gravity of Wood. Tech. Note No. B–14, Forest Products Laboratory. Describes various methods of determining specific gravity of wood, as well as proper techniques to employ in making determinations. Determination of moisture content also explained.

Effect of High-Energy Cathode Rays on Cellulose. J. F. Saeman, M. C. Millett, E. H. Lawton. (reprinted, Industrial and Engineering Chemistry) Explains tests made to determine feasibility of improving dilute acid saccharification of cellulose by subjecting material to irradiation with high-energy cathode rays. Tests show reduction of crystallinity of cellulose is definitely obtainable, but dosage of ionizing radiations required too great to be of immediate importance.

Log Trailer Transfer Unit (Improved Harvesting Methods). Describes method for transferring trailer, log load and front bunk from heavy duty primary tractor units to smaller highway units. System makes possible more efficient use of equipment, hauling of more board feet per day with less units. U.S.F.P.L. Report No. D1637–52.

Rubber-Tired Skidders (Improved Harvesting Methods). U.S.F.P.L. Report No. D1637–50. Describes various rubber-tired skidders for harvesting low-quality and small-diameter timber. Such equipment makes harvesting of above materials economical by making possible more payloads per day.

Chain Bundling (Improved Harvesting Methods). U.S.F.P.L. Report No. D1637–49. Describes efficient, safe chain grip and release for chain bundling of pulpwood and small logs.

A Hundred Definitions Pertaining to Wood and Other Forest Products. U.S.P.F.L. Tech. Note No. 240. Brief definitions of many terms known to the layman, and others generally known to those in the industry. Terms are selected from most fields in wood technology.

Comparative Strength of Air-Dried and Kiln-Dried Wood. U.S.P.F.L. Tech. Note. No. 180. Explains briefly that good kiln drying and good air drying have same effect on strength. Also explains apparent difference in strength as resulting variations in moisture content, appearance, etc.

Goncalo Alves. Jeannette M. Kribs. U.S.F.P.L. Report No. R1934. Describes area of growth (eastern Brazil, and upland forests of other south and central American countries as far north as Mexico) and describes various properties, characteristics, and uses. Uses include fine furniture, structural, ties, shipbuilding, floorings, trim, pianos and many others. Goncalo is generally highly valued for its strength, durability and beauty.

The Determination of Copper in Wood Pulps With Tetraethylenepentamine. R. M. Kingsbury and C. L. Lake, U.S.F.P.L. (reprinted from Tappi, Vol. 35, No. 11, Nov. 1952) Describes simple and rapid test for colorimetric determination of copper in cellulosic material. Sample of material is digested with nitric, sulphuric, and perchloric acids, is neutralized, and blue complex is developed with tetraethylenepentamine. Amount of copper is determined by comparing transmittancy of the solution to that of standard copper solutions.

Paper-Honeycomb Cores for Structural Sandwich Panels. Robert J. Seidel, U.S.F.P.L. (Reprinted from The Paper Industry). Explains various types of honeycomb core construction for sandwich panels—their construction and relative advantages. Describes types of facings usable, with strength comparisons for various wood products facings. Other properties are related.

Today's Semichemical Pulp Industry. J. A. Hall, U.S.F.P.L. (reprinted from Southern Pulp and Paper Manufacturer, Dec. 1952) Discusses significance of semi-chemical as related to pulpwood utilization and as means of extending raw pulp materials to cover ever-increasing demands for paper products. Process gives large pulp yields and is applicable to currently little used low grade hardwoods.

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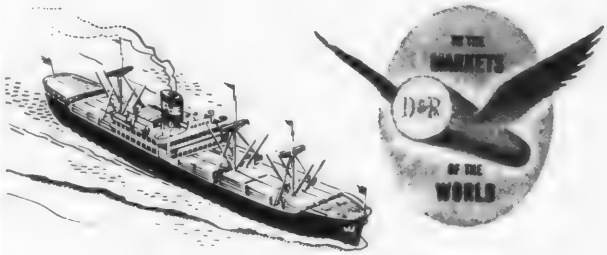

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". . . has paid for itself several times."
Texarkana Lumber & Supply Company

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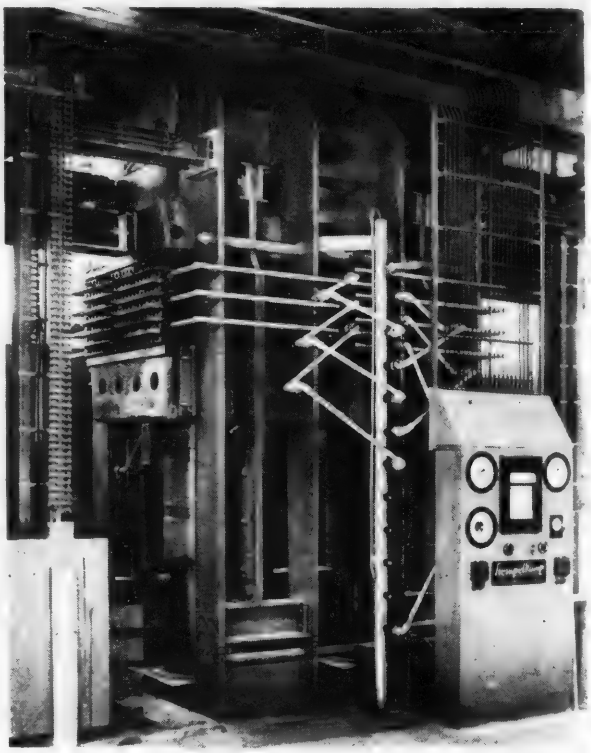
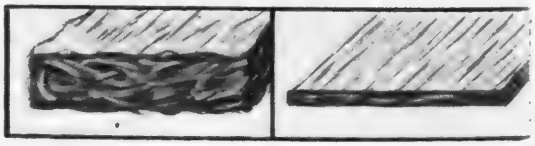


This Siempelkamp Chipboard Press (dry process) automatically loads pre-pressed material (below, left), places it under pressure of 356 p.s.i., then unloads cured boards (below, right).



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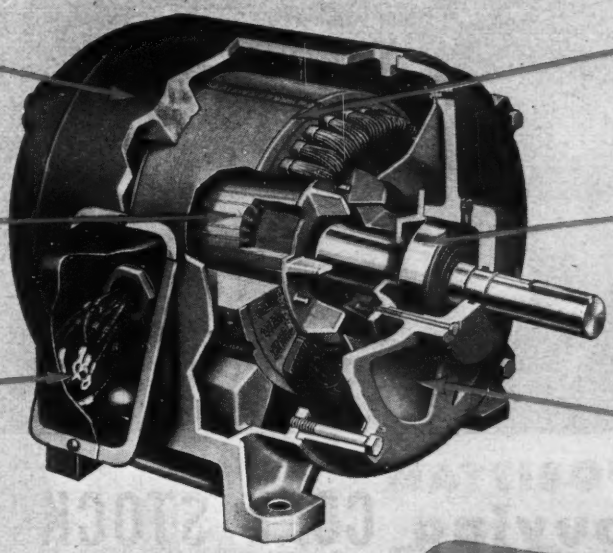

1

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2

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3

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4

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5

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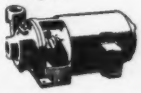

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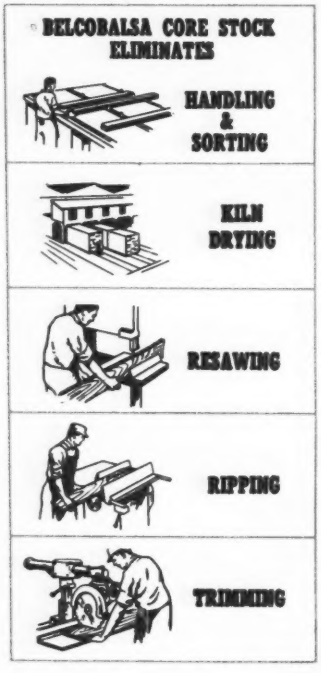

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